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BACTERICIDAL EFFECTS OF ALGAE ON ENTERIC
ORGANISMS

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Texas University
Austin, Texas

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Sunfish	<u>Lepomis gibbosus</u>
Bullfrog	<u>Rana catesbeiana</u>
Spotted salamander	<u>Ambystoma maculatum</u>

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BACTERICIDAL EFFECTS OF ALGAE

ON ENTERIC ORGANISMS

by

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ABSTRACT

A series of experiments involving the effects of blue-green and green algae on the dieoff rates of selected bacteria have been conducted. The algae were axenic cultures of Anabaena cylindrica, Anacystis nidulans, Gloeocapsa alpicola, Oscillatoria chalybia, O. formosa, Phormidium faveolarum, Ankistrodesmus braunii, Chlorella pyrenoidosa, C. vulgaris, and Scenedesmus obliquus. Cultures of enteric bacteria species (Alcaligenes faecalis, Enterobacter aerogenes, Escherichia coli, Proteus vulgaris, Pseudomonas aeruginosa, and Serratia marcescens) were added to the axenic algal cultures during different periods of the algal life cycles.

Cultures of the normal blue-green contaminants were exposed to the enterics to determine antagonistic effects toward the enterics. Filtrate from actively growing algae was exposed to cultures of enterics to determine whether any antibiotic compounds were imparted to the medium during lag phase growth of algae. To determine aftergrowth of the enteric species, the duration of the tests was extended to about 90 days. Mixed cultures of green and blue-green algae were exposed to both single species of enteric bacteria and mixed cultures. The results indicated that mixed algal cultures cause a greater dieoff among the enteric bacteria than do individual species of algae. The dieoff characteristics of pathogenic species, namely, Salmonella typhosa, S. paratyphi, Shigella dysenteriae, S. paradysenteriae, and Vibrio comma were also determined.

The pathogenic species did not survive as long as the enteric test species under similar test conditions. Virtually no aftergrowth was detected on the part of the pathogens.

CONCLUSIONS

The following conclusions are derived from the results of this investigation.

1. Dieoff coefficients for individual species of enteric bacteria in the presence of axenic cultures of algae were comparatively low, the majority of the coefficients being near or less than -0.1 per day. Chlorella pyrenoidosa and Chlorella vulgaris caused the highest dieoff coefficients among enteric bacteria. Chlorella spp. were substantially more effective than Ankistrodesmus braunii or Scenedesmus obliquus in effecting accelerated dieoffs.

2. Mixed cultures of either the blue-green or green algae caused significantly higher dieoff coefficients among the enteric test bacteria as well as the pathogenic bacteria tested. The majority of the coefficients were between -0.1 and -0.2 per day.

3. Effects exhibited by enteric bacteria on the growth of individual algal species depended on the algal species in question. Constant patterns of increased or decreased algal growth coefficients were uncommon. In the majority of algae species, a slight inhibition of the overall growth potential of the algae was observed.

4. Dieoff of enteric bacteria was more rapid under aerobic conditions than anaerobic conditions.

5. Aftergrowth of Escherichia coli, Pseudomonas aeruginosa, and Serratia marcescens occurred in axenic blue-green algal cultures as well as in waste stabilization pond effluent. Alcaligenes faecalis, Enterobacter aerogenes, Proteus vulgaris, Vibrio comma, Salmonella typhosa, Salmonella paratyphi, Shigella paradysenteriae exhibited no aftergrowth potential under similar conditions. Serratia and Pseudomonas exhibited a greater aftergrowth potential than did E. coli.

6. As the algal species reached their stationary and/or log death-growth phase in the laboratory, quantities of organic carbon were released to the medium; up to 200 mg/l was not uncommon. Prolonged survival periods and/or aftergrowth by some of the enteric bacteria were attributed to this nutrient source.

7. Consistent dieoff effects on enteric bacteria in laboratory and field waste stabilization ponds were achieved only after appropriate periods of acclimitization of the pond microcosms. Those periods were observed to be as long as 30 days, or more in some instances. Dieoff coefficients for early stages in pond treatment units were higher than those obtained for secondary stages such as maturation ponds. Higher coliform concentrations and increased competition for nutrient sources in early treatment sequences were attributed to that rapid dieoff.

8. Compared to axenic algal culture experiments and laboratory scale ponds, the most rapid reduction in enteric bacteria occurred in the waste stabilization ponds located in the field.

9. In laboratory ponds, E. coli exhibited a greater resistance to dieoff than did Pseudomonas aeruginosa or Serratia marcescens; but in the field ponds, E. coli exhibited the highest rate of dieoff of any enteric bacterial species tested.

10. Occasional increases in concentrations of Pseudomonas and Serratia were noted in laboratory and field ponds. Short-circuiting was not considered to be the causative factor, but an association of these two genera and other enteric bacteria with clumps of algae might have been responsible for this increase. Pseudomonas spp. exhibited increases in numbers when the total algal concentrations were lowest in both the laboratory and field ponds.

11. Total coliform bacteria counts decreased significantly during periods when the pond phytoplankton population was highest, and vice versa.

12. The vast majority of bacteria in all pond effluents were of the group of bacteria referred to as the chromagens; included in the group are Flaveobacterium and Brevibacterium. Cultures of these two separate

genera were shown to exert marked antagonistic effects on enteric bacteria when together in culture. Flaveobacterium was more antagonistic to enteric bacterial species than Brevibacterium.

13. On several occasions extended periods of incubation were necessary to produce any recordable growth of Pseudomonas spp. from waste stabilization pond samples using either nutrient, trypticase soy, or Endo agar plates. Special consideration should be given this factor when total or enteric counts are made from wastewater environments.

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CHAPTER 1

INTRODUCTION

An important reason for the treatment of domestic wastewaters is the reduction or elimination of the enteric bacteria from these wastewaters; in this connection, waste stabilization ponds have been used successfully. In established ponds the most obvious population consists of various species of algae as evidenced by their pronounced color. These algae, under proper pond design, can produce the greater percentage of required dissolved oxygen and can interact with the entire biological community. As yet, however, the specific role that algae play in the overall reduction of enteric bacteria in waste stabilization pond systems has not been firmly established.

The purpose of this investigation was to determine the degree of toxicity exerted by typical species of blue-green and green algae on representative bacteria found in wastewaters. The scope of this investigation included: (a) long-term studies involving selected species of algae, coliform bacteria, and pathogenic bacteria; (b) bactericidal and bacteriostatic effects; (c) algal culture filtrate effects on bacteria test species; (d) aftergrowth capabilities of test bacteria by extension of study periods; and (e) enteric bacteria dieoff investigations in both laboratory waste stabilization ponds and field ponds having different design characteristics.

Bacterial Characteristics

A brief description of some of the important characteristics of the bacteria studied in this investigation is appropriate in order that their complexity and the significance of their reduction in wastewaters can be fully appreciated. Coliform bacteria are, by definition and description, inclusive of all aerobic and facultative anaerobic, gram-negative, nonspore-forming rod shaped bacteria which are capable of fermenting lactose with gas formation within forty-eight hours at a temperature of 35 degrees

Centrigrade (27). They have been variously named the B. coli group and the coli-aerogenes group in past years with no change in the specifications. By this definition, therefore, only part of the bacterial flora inhabiting the gastrointestinal tract of animals are coliforms. The total number of genera which are capable of living in those conditions is largely unknown. Invariably, species and varieties of Escherichia, Streptococcus, Clostridium, Aerobacter (renamed Enterobacter), Paracolobactrum, Salmonella, Shigella, Proteus, Pseudomonas, Alcaligenes, Serratia, and Bacteriodes are among those found. In this sense any species which has the capability to survive and multiply in any intestinal tract could be called an enteric bacterium. Taxonomically, the enteric bacteria follow this classification (26):

Order Eubacteriales

Family Enterobacteriaceae

- Genus Escherichia
- Genus Aerobacter
- Genus Klebsiella
- Genus Paracolobactrum
- Genus Alginobacter
- Genus Erwinia
- Genus Serratia
- Genus Proteus
- Genus Salmonella
- Genus Shigella

Other genera which are found routinely in domestic wastewaters have the following classification:

Order Eubacteriales

Family Achromobacteraceae

- Genus Alcaligenes

Order Pseudomonadales

Family Pseudomonadaceae

- Genus Pseudomonas

To assume that all of the species of the genera listed in the above classifications are nonpathogenic would be erroneous. Several species in the Family Enterobacteriaceae, for example, have been known to be pathogenic to man, producing various intestinal diseases and septicemic infections. For this reason alone their elimination from wastewaters is of utmost

importance. Alcaligenes faecalis has been isolated from infections of bacteremias, gall bladder infections, eye infections, and has frequently been incriminated in cases of enteritis. Species of Pseudomonas, by the same token, are frequently encountered in eye and ear infections as well as urinary tract infections (26). This genus is universally treated with a great deal of respect, especially in facilities in which burn patients are housed. A septicemia caused by Pseudomonas may occur as frequently as staphylococcal septicemia in severely burned patients and in persons who have leukemia. The outcome is usually fatal.

The genus Vibrio, which has several nonpathogenic water-borne species, is also found in the Family Pseudomonadaceae. Most dangerous of the species are Vibrio comma and Vibrio El tor which are the causative agents of the well-known Asiatic cholera.

Review of Literature

The mechanism by which populations of undesirable bacteria are reduced in numbers has been the subject of many investigations. In waste treatment facilities the bacterial dieoff is affected by several factors. In lakes, reservoirs, impoundments, and streams the bacterial dieoff may be assumed to be similar insofar as these factors are concerned. The principal difference between the aquatic environments is one of bacterial concentration. Some of the factors which undoubtedly play an important part in the bacterial dieoff mechanism are sunlight, pH changes, changes in oxygen tension, predation by other organisms such as rotifers, changes in organic content of the water, temperature, and antagonistic effects of other bacterial species and other faunistic species such as fungi and algae. Gravel, et al. (2) found temperature, pH, and dissolved oxygen concentration to be important, in that order, in dieoff rates of reservoir coliforms. Gameson and Saxon (3) attributed the dieoff primarily to sunlight effects.

Bacteria must have certain quantities of organic carbon present for their survival or multiplication. Ward and Moyer (14) reported that organics excreted by algae during growth could serve as bacterial nutrient sources. This source of carbon may reach appreciable concentration levels. Hellebust (13) reported that some phytoplankton are capable of excreting up to 25

percent of their photoassimilated carbon during their log growth phase. Therefore, when large populations of algae are present, adequate supplies of carbon should be present for the survival of some of the coliform bacteria. Data presented by McGrew and Mallette (10) stated that some bacteria of intestinal origin, including Escherichia coli, could survive and even multiply at concentration levels of glucose less than 5 micrograms per milliliter.

The literature contains various reports of interactions between coliforms and other faunistic species such as algae. McLachlan and Yentsch (17) and Nakamura (18), respectively, found that certain bacteria enhanced the growth of Dunaliella and Chlorella. Ward and Moyer (14) and later Ward, Moyer, and Vela (25) demonstrated that there was significant reduction in growth of Chlorella pyrenoidosa when in the presence of Pseudomonas aeruginosa. Opposing opinions can be found regarding the antagonism of microorganisms to one another. Guthrie et al. (11) and Geldreich and Clarke (4) have identified inhibition characteristics between Pseudomonas aeruginosa and Escherichia coli under different environmental conditions.

The interactions which occur between bacteria and algae may affect the physiology and productivity of an aquatic community. Stimulation of bacteria by algae or algal exudates has been reported by the following investigators. Recent work by Vela and Guerra (52) and Ward, et al. (25) furnished evidence that, in some cases, the proliferation of bacterial species may be a function of algal growth. In tests involving Shigella, Proteus, Staphylococcus, Streptococcus, and Corynebacterium they found rapid dieoff patterns of these bacteria when exposed to Chlorella. Yet, it was also reported that Salmonella typhi and Salmonella paratyphi grew well in the presence of Chlorella. In extensive works on toxic blooms of blue-green algae, Gorham (36) found that Microcystis produced a toxin but stated that it did not inhibit bacteria such as Bacillus subtilis, Staphylococcus aureus, Escherichia coli, and Pseudomonas hydrophila. It was hypothesized that the age of the culture may have been an important factor in the results and should be considered when analyzing future data. Fogg (15, 16) also reported stimulatory effects to bacteria when associated with

algae. He attributed those effects to extracellular by-products of the algae. Lefevre (37) substantiated earlier hypotheses that the extracellular products did exist.

The numbers of reports which conclude that algae may be inhibitory to bacterial growth are in the majority. Geldreich and Clarke (4) reported that fecal coliform bacteria were influenced adversely by Schizothrix calcicola within 24 hours. Telutchenko and Fodorov (5) concluded that their algae affected the test bacteria by using the carbon dioxide and, thus, shifting the pH, by releasing antibacterial substances, by inhibiting the bacteriophage which lyse bacteria, and by increasing the organic content which stimulated the growth of the bacteria. They further concluded that Chlorella vulgaris was more efficient than Scenedesmus obliquus in killing E. coli and Salmonella typhimurium. Chlorella vulgaris was the test algal species used by Pratt and Fong (19). Their conclusion was that that species of Chlorella was capable of inhibiting the growth of associated bacteria.

Birge and Judey in 1929 (28) indicated that algae may have a role in reducing the numbers of bacteria in water. To date only "Chlorellin" has been named specifically with regard to its antibacterial characteristic by Caldwell (30), Pratt (46), and Spoehr, et al. (50). Flint and Moreland (35) were able to demonstrate that metabolic exudates of certain blue-green algae were toxic to bacteria but carried the report no further. Neel and Hopkins (43) observed the reduction in numbers of types of coliforms during seasons of the year in which prolific algal growth occurred in the ponds. Work by Vladimirava (53) reported that cultures of Chlorella pyrenoidosa were definitely capable of suppressing bacterial growth. Prescott (47) cited two genera, Microcystis and Chlorella, as being capable of producing and secreting substances active against two bacterial genera, Staphylococcus and Clostridium. Oswald and Gotaas (45), in an extensive work dealing with pilot-plant waste stabilization ponds, proposed that no specific anticoliform activity could be credited to an algal culture tested in the laboratory. However, they did not discount the possibility of antibacterial properties of algae.

The problem of bacterial contamination has been overlooked by some investigators and this is of importance when testing single species of algae. It is doubtful that there are many bacteria-free cultures of filamentous blue-green or green algae. Unicellular or diplo forms of blue-greens and greens are relatively easy to grow in a bacteria-free state. In naturally contaminated cultures, Ward and Moyer (14) reported that the bacterial mass was less than one percent of the algal mass. Yet, the numbers of bacteria were shown to exceed a million per milliliter; figures approaching a billion per milliliter were not uncommon. As to the contaminants themselves, Krauss and Thomas (20) reported Flavobacterium to be the most common and persistent genus in cultures of Scenedesmus obliquus. Levinson and Tew (21) also reported Flavobacterium as a contaminant of their research cultures of algae. Their test species was Chlorella vulgaris.

Numerous reports are available which quote reductions in the coliform numbers through waste stabilization ponds. The reduction percentages are usually impressive; however, as Geldreich (1) pointed out, even with reductions of from 90-99 percent the remaining 1-10 percent of the coliforms may easily constitute numbers of from 4×10^6 to 10×10^6 per 100 milliliters. These values are not acceptable for more effluent standards. Most of the species incorporated in the coliform group obviously have a similar metabolic pattern of growth and development. Geldreich (7) and Gallagher and Spino (8) have observed similar survival characteristics (or death rates as the case may be) among the more abundant coliform species. In making observations on streams, Churchill (9) reported that the slopes of die-away curves for the total and fecal coliforms were essentially the same. While figures are usually the best measure of coliform dieoff when describing their functions, it must be remembered that a rate number does not relate the environmental conditions. In reports dealing with enteric bacteria reduction in ponds and series of ponds in South Africa and Zambia, Marais and Shaw (40), and later Marais (38, 39) used a value of $K = 2.0$ for E. coli and $K = 0.8$ for Salmonella typhi. These differences between only two species indicate the need for further data. Projections made by use of the modifications of Chick's Law as reported by Marais (38, 39)

may be used effectively to provide an insight into what general bacterial pollution control may be required. Hanes, *et al.* (6) reported log death rates of 0.134/day, 0.291/day, and 0.355/day respectively at temperatures of 10°, 20° and 30°.

It is apparent that not enough information is available on pathogenic bacteria such as Salmonella, Shigella, and Vibrio. With large numbers of coliforms present, the probability of finding Salmonella, for example, increases. Of course, with several hundred serotypes of Salmonella in existence, it would be difficult to establish the exact nature of the type found in the sample. Geldreich (12) reported that when the fecal coliform count exceeded 1,000, the Salmonella also increased. Periodic reports of isolation of various species of Salmonella are routine (22). In March 1969, 1,165 isolations of Salmonella were reported for humans, an average of 291 per week. This was an increase of 13.2 percent over the average for February 1969, and an increase of 7.0 percent (weekly) for March 1968. At the same time, 738 non-human isolations occurred during March 1969. These figures indicate that, even through few outbreaks of disease caused by Salmonella are occurring in this country, the causative agents are ever-present. Ward and Moyer (14) reported that Salmonella typhi and Salmonella paratyphi grew well in algal cultures for periods of time extending through seven days. Sidio (48) reported up to 99 percent removal of coliforms along with complete removal of the pathogenic genus, Salmonella. There is additional evidence to indicate that Salmonella typhi survival is dependent on the available supply of nutrients. Increased loadings with shorter retention times were seen to support the survival of the typhoid bacillus. This was reported by McGarry and Bouthillier (41). They also reported that ponds with longer detention times and reduced nutrient concentrations provided a more antagonistic environment. Goetzee and Fourie (31) showed in field studies that waste stabilization ponds operating in series were capable of reducing Salmonella spp. by at least 99.5 percent. The total reduction of E. coli was similar to that found for other bacteria. These investigators reported that Salmonella spp. was more resistant, as compared to E. coli, in highly polluted waters.

Generally, the operating data on waste stabilization ponds are well documented (54, 55, 56, 57, 58, 59). Smallhorst and Walton (49) and Towne, et al. (51) have observed and reported the reduction of enteric organisms in waste stabilization ponds. They attributed this reduction primarily to detention. Towne, et al. (51) also reported that the reduction in coliform numbers was not appreciably different for the seasons despite variations in algal concentrations. Detention coupled with short-circuiting was considered by van Eck (32, 33, 34) and Bolitho (29) to be the most important parameter which influenced bacterial concentration. Reductions in coliform bacteria of above 90 percent routinely occur in ponds which are functioning in an acceptable manner (42, 48, 54). Gann, et al. (23) found Achromobacter 65 percent of the total population of pond bacteria, Pseudomonas 25 percent, Flaveobacterium 5 percent, and the coliforms less than (or rarely equalling) 10 percent.

One aspect of the dieoff of bacteria in treatment facilities which has received very little attention has been the aftergrowth phenomenon. After treatment and discharge, the surviving bacteria, including those which have been exposed to chlorine, may find suitable growth conditions in the receiving waters and continue to multiply. This aftergrowth has been reported by Orlob (44), Geldreich (12), Eliassen (24) and others. Under certain conditions coliform bacteria were found to increase in numbers to peak values within 30 hours up to 10-40 times the original number (24). Even with chlorination of 15 minutes duration, a lesser increase in aftergrowth occurred of 1-12 times the original number of bacteria. Clearly a greater understanding of the ability of these organisms to reproduce and the accompanying necessary conditions is needed.

CHAPTER 2

MATERIALS AND METHODS

Algal and Bacterial Cultures

Standard microbiological laboratory procedures were incorporated during all phases of this investigation. Algal species were maintained as bacteria-free as possible under normal laboratory conditions prior to additions of the test bacteria. The axenic algal cultures were subjected to transfer from a solid algal growth medium to a liquid medium, and vice versa, for a period of three years prior to the initiation of the experimentation. Their acclimation to laboratory growth conditions and growth rate constancy was, therefore, assured. The composition of the liquid medium which was used for the culture of the algae in the laboratory is described in Table 2-1. This medium was designed to allow optimum growth of the algae for prolonged periods of time, a feature which was of great benefit during the extended periods of testing necessary for successful completion of the investigation. Table 2-2 presents a breakdown of the elemental concentrations in the algal growth medium shown in Table 2-1.

Throughout the laboratory phase of the investigation six species of blue-green algae and four species of green algae were used as test organisms. These species are listed in Table 2-3 along with the bacteria which were tested. Code numbers for the algae indicate their culture number as cataloged by the culture collection group at Indiana University from where they were obtained. Code numbers for the bacterial species represent the American Type Culture Collection number or the culture number from stock cultures at North Texas State University or both.

The algae were grown in culture and used in tests at a temperature of $25 \pm 1^{\circ}\text{C}$. Fluorescent lighting operating on a cycle of 14 hours on and 10 hours off provided an intensity of 290-300 foot-candles.

All of the bacterial species were cultured in the laboratory with trypticase soy broth or agar supplemented with 2 g/l yeast extract. Appropriate serial dilutions were made of the cultures followed by counting

Table 2-1. Composition of Algal Culture Medium

Compound	Final Concentration (mg/l)
NaHCO_3	200
MgSO_4	75
$\text{NaSiO}_3 \cdot 5\text{H}_2\text{O}$	20
$\text{Ca}(\text{NO}_3)_2$	50
KH_2PO_4	20
NH_4NO_3	75
KNO_3	40

Trace Element Solution (1 ml of the following mixture)

EDTA	10.0 g/l
$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	1.0 g/l
H_3BO_3	1.0 g/l
$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$	0.5 g/l
$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	0.5 g/l
$\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$	0.15 g/l
$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	0.15 g/l
$(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$	0.10 g/l
LiCl	0.0278 g/l
$\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$	0.0556 g/l
$\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$	0.0278 g/l
KI	0.0278 g/l
KBr	0.0278 g/l

Distilled Water, to make 1 liter final volume

The pH of the above medium is adjusted to ≈ 5.8 with HCl before autoclaving, resulting in a final pH of ≈ 7.4

Table 2-2. Element Concentrations in Algal Culture Medium

Element	Final Concentration (mg/l)
N	41.15
K	21.245
P	4.560
Na	58.468
C	31.825
Cl	102.755
S	20.146
Mg	15.150
Ca	12.200
Si	2.960
Zn	0.228
B	0.174
Mn	0.139
Fe	0.101
Co	0.037
Cu	0.038
Mo	0.054
Li	0.004
Al	0.004
Sn	0.015
I	0.021
Br	0.019

Table 2-3. Algae and Bacteria Test Species

Organism	Code Number
<u>Anabaena cylindrica</u>	B 629
<u>Anacystis nidulans</u>	625
<u>Gloeocapsa alpicola</u>	B 589
<u>Oscillatoria chalybia</u>	B 386
<u>Oscillatoria formosa</u>	LB 390
<u>Phormidium faveolarum</u>	B 427
<u>Ankistrodesmus braunii</u>	245
<u>Chlorella pyrenoidosa</u>	26
<u>Chlorella vulgaris</u>	29
<u>Scenedesmus obliquus</u>	72
<u>Alcaligenes faecalis</u>	ATCC 8748
<u>Enterobacter aerogenes</u>	ATCC 9621
<u>Escherichia coli</u>	ATCC 8677 NT 201
<u>Proteus vulgaris</u>	ATCC 8427
<u>Pseudomonas aeruginosa</u>	ATCC 7700 NT 99
<u>Serratia marcescens</u>	ATCC 13880
<u>Salmonella paratyphi</u>	NT 113
<u>Salmonella typhosa</u>	NT 118
<u>Shigella paradysenteriae</u>	NT 131
<u>Shigella dysenteriae</u>	NT 127
<u>Vibrio comma</u>	NT 154

and enumeration of the bacterial colonies on poured plates of the trypticase soy agar. This mixture of nutrient sources was found to be superior to nutrient broth or nutrient agar alone for growth and subsequent enumeration of most of the test species. In tests involving laboratory cultures of algae and bacteria, counts were made after 24 hours of incubation at 37°C. The plates were then returned to the incubator and recounted at 48 and 72 hours because, in the majority of cases, the algal contaminants and some of the test bacteria did not show adequate growth at 24 hours for accurate enumeration. This recounting technique is time-consuming but necessary.

Two genera of bacteria were the primary contaminants of the filamentous blue-green test algal species. These were Brevibacterium and Flavobacterium and were identified through selective testing procedures by Dr. R. K. Guthrie. Their presence was not detected in the test cultures of green algae.

Addition of test bacterial populations to algal cultures was uniformly controlled throughout the investigation. A standard straight-wire inoculum of the bacterial species in question was incubated for 24 hours in half strength TS broth. The solution was mechanically agitated and 0.05 ml was transferred to each 100 ml of algal culture. Before removing samples from the algal cultures the volume of each 250 ml erlenmeyer flask was adjusted with sterile distilled water to correct for evaporation losses. After making appropriate serological dilutions the samples were plated onto TS agar and counted.

Laboratory Investigation Series Identification

The first phase determined the effects that axenic cultures of blue-green and green algae had on the dieoff of individual species of test bacteria. Additional tests involved studies of algal growth characteristics when exposed to the bacteria and studies of the effects of the contaminating bacteria on various enteric species. The tests are described below.

Series I. Viable bacteria were added to individual algal cultures at controlled times (early to mid-log growth phase of algae) and the bactericidal or bacteristatic effects noted. This series of tests was coded BG-I (blue-greens) and G-I (greens).

- Series II. Viable bacteria were added to individual axenic cultures of algae during the first twenty-four hour period of the lag growth phase after inoculation of the algae into sterile growth medium. Any inhibition of algal growth was determined by this timing sequence. The series was coded BG-II and G-II.
- Series III. Control tests were conducted to evaluate normal cyclic influences of contaminant bacteria in algal cultures. This series was coded BG-III and G-III.
- Series IV. Algal mass was determined by weighing procedures. Comparison of these data from control cycles with data obtained during Series I and II demonstrated whether inhibition or enhancement of algal cultures was the result of the presence of enteric bacteria. This series was coded BG-IV and G-IV.
- Series V. Dieoff rates of the contaminant bacterial species were determined during series involving the additions of enteric bacteria in algal cultures. This series was coded BG-V or "contaminants."
- Series VI. Dieoff rates of the enteric bacteria alone in algal growth medium were analyzed. This series provided the basic control for the study described in Series V above. This series was coded VI.
- Series VII. Separation of the algal growth medium into a cell-free filtrate during mid-log phase of algal growth control with subsequent inoculation of enteric bacteria demonstrated the influences of algal metabolic exudates on the enteric bacteria. This series was coded BG-VII and G-VII.
- Series VIII. Equal quantities of each of the six test species of blue-green algae were mixed when in their mid-log growth phase. Additions of suspensions of individual species of enteric bacteria in each resulting

heterogeneous algal culture demonstrated comparative dieoff rates with Series I and II above. This study was conducted with the blue-greens and the greens separately and was coded BG-VIII and G-VIII.

Series IX. Duplication of series BG-VIII and G-VIII using mixtures of all the enteric bacterial test species provided bacterial dieoff rates which might be expected from field conditions. This series was coded BG-IX and G-IX.

Series X. Testing in the majority of the series was continued for periods up to 90 days to establish patterns of aftergrowth of each bacterial species. This series was coded BG-X and G-X.

Laboratory Data Analyses Methods

Data for all of the series, I through X, and for the runs involving the pathogenic bacteria, were analyzed using a method of least squares. The program (BETA) is shown in Appendix C. It should be noted that when aftergrowth occurred, the data were not subjected to statistical analysis. In order to be acceptable, only decreases in numbers which extended over periods of 90 days were programmed. Data for aftergrowth characteristics are presented separately. Basically, the function of program BETA was the calculation of the constants for an equation similar to the following:

$$Y = C_0 + C_1 X_1 + C_2 X_2 + C_3 X_3 + \dots + C_n X \quad 2-1$$

Y is the dependent variable, X is an independent variable, and C is constant. Equation 2-2 was used to calculate the log (base 10) death rates:

$$\log (Y) = C_0 + C_1 X_1 \quad 2-2$$

where

Y = the density of bacteria in number per ml, or mg/l weight

C_0 = the Y-axis intercept

X_1 = the time in days corresponding to Y

C_1 = the death rate coefficient, log base 10

Additional computer output provided: (a) the variance ratio from the horizontal line; (b) variance about the regression line; and (c) the multiple correlation coefficient. Data were analyzed at the 90 percent confidence limit.

Laboratory and Field Waste Stabilization Pond Studies

Additional data were obtained from model waste stabilization ponds. These laboratory units consisted of two serial connected aquaria similar to those described by Malina and Yousef (60). The total capacity was 46 liters. A diagram of these units is shown in Figure 4-1. All of the model pond experiments were conducted at ambient temperature on location at the Govalle Wastewater Treatment Plant in Austin, Texas. Lighting was provided by banks of fluorescent bulbs held at approximately 25 cm above the water surface. The intensity was 325-350 foot-candles during the 12 hours they were cycled.

Three different design concepts were represented by the model ponds. The volumes and detention times were calculated to correspond to the series of full-scale ponds existing at the Govalle facility. The first set of ponds consisted of an anaerobic pond followed by two 46-liter facultative ponds and a maturation pond. The second set was represented by facultative ponds which contained an anaerobic "trench," followed by a maturation pond. The third set contained facultative ponds followed by a maturation pond.

Daily additions of 500 ml untreated domestic wastewater were added to each model pond; a similar quantity was removed from the opposite end to effect a balanced system, and evaporation losses were corrected by the addition of tap water.

CHAPTER 3

LABORATORY CULTURE DIEOFF EXPERIMENTS

Regardless of the degree of laboratory control, considerable variance occurred in the bacterial population during some of the tests. These fluctuations in numbers were mainly attributed to the growth phase of the algal cultures and the inherent nature of bacteria to adhere to filaments or aggregates of algae. The fluctuations also resulted in low multiple correlation coefficients and high variances. All results of the analyses made during the laboratory axenic culture series are presented in Tables A-1 through A-72 of Appendix A. Those data represent the analyses of laboratory data as taken from program BETA printouts.

Column headings in Tables A-1 through A-72 inclusive, Appendix A are as follows:

- N = number of data points used in computing that particular regression line
- S_H^2 = the variance of data points about the mean of all data points
- S_r^2 = the variation of data points about the regression line
- S_H^2/S_r^2 = the variance ratio which if referenced against appropriate standard "F" tables would indicate the statistical validity of the data
- b = calculated y - intercept
- k = the dieoff (-) or growth (+) rate coefficient of the typical $C_t = C_0 10^{kt}$ formulation
- R = the multiple correlation coefficient

The numbers of data points indicated for each experiment do not necessarily correspond to the total number obtained during the duration of the run. Where significant aftergrowth of test bacterial populations occurred, the test results were not included in the computer program and those data are discussed separately.

Enteric Bacteria Dieoff Studies

Although single species of bacteria do not exist in nature with axenic cultures of algae, without these basic data it would be impossible to assess the true value of each algal species with respect to its effect on the dieoff rate of the bacteria in question. Dieoff rate coefficients for virtually all of the laboratory series involving axenic algal cultures and enteric bacteria are presented in Table 3-1. Considering the series involving the blue-green algal test species, it is easily discernible that no two species exerted the same dieoff effect on any two bacterial species. Additionally, the dieoff rate coefficients vary considerably. One primarily important conclusion which is derived after examination of the data in Table 3-1 is that the comparatively rapid dieoff rates of enteric bacteria which occur in nature are apparently not due to the effects of individual algal species.

Differences in the dieoff rate coefficients (hereinafter called "coefficients") between series BG-I and BG-II were minimal. There was little difference in the effects which algae had on the dieoff rates of the test bacteria when the algae were exposed to the bacteria during algal log growth phase (Series BG-II) or algal log growth phase (Series BG-I). Several of the coefficients seen in Table 3-1 appear with relatively high ranges, as for example, filtrate of Anabaena cylindrica and Alcaligenes faecalis, $-.0230 \pm .0570 \text{ day}^{-1}$. As in this example, some actually exceed the numerical values of the coefficients themselves. It is believed that significant fluctuations occurred in the bacterial populations throughout the experiment duration because of aggregation and adhesive phenomena which are constantly occurring. For these reasons the seemingly high coefficient ranges are not to be regarded as errors.

On the other hand, comparatively low coefficients were due to the abilities of the test bacteria to derive nutritional benefits from the cellular materials of the blue-green algae. One such material was the gelatinous matrix which is a characteristic of all the blue-green algae. Additional evidence of these occurrences can be seen by the coefficients derived from the tests using blue-green algal filtrate. On a comparative basis it appeared that prolonged survival of enteric bacteria occurred when blue-green algae were present as compared to green algae.

Table 3-1. Dieoff Coefficients for Series Utilizing Axenic Algal Cultures and Enteric Bacteria.

Series	Alcaligenes faecalis*	Enterobacter aerogenes*	Escherichia coli*	Proteus vulgaris*	Pseudomonas aeruginosa*	Serratia marcescens*
<u>Anabaena cylindrica</u>						
Mid-log inoc. BG-I	-.0774 ± .0192	-.0854 ± .0107	-.0397 ± .0125	-.1000 ± .0213	-.0512 ± .0241	-.0366 ± .0404
Contaminant retn. BG-I	-.0157 ± .0526	-.0175 ± .0147	-.0173 ± .1320	-.0046 ± .0118	-.0154 ± .0066	-.0027 ± .0072
Day-0 inoc. BG-II	-.0582 ± .0419	-.0816 ± .0557	-.1132 ± .0534	-.0687 ± .0307	-.0702 ± .0104	-.0583 ± .0249
Contaminant retn. BG-II	-.0187 ± .0054	-.0159 ± .0128	-.0175 ± .0258	-.0094 ± .0215	-.0198 ± .0163	-.0234 ± .0157
Filtrate BG-VII	-.0230 ± .0570	-.0316 ± .0832	-.0164 ± .0575	-.0253 ± .1009	-.0167 ± .0548	-.0118 ± .0494
<u>Anacystis nidulans</u>						
Mid-log inoc. BG-I	-.1145 ± .0260	-.1172 ± .0239	-.0796 ± .0137	-.0899 ± .0161	-.0614 ± .0158	-.0480 ± .0099
Contaminant retn. BG-I	-.0051 ± .0275	-.0078 ± .0099	-.0114 ± .0105	-.0177 ± .0453	-.0589 ± .1216	-.0147 ± .0059
Day-0 inoc. BG-II	-.0640 ± .0320	-.0448 ± .0225	-.0596 ± .0149	-.0522 ± .0470	-.0474 ± .0136	-.0437 ± .0306
Contaminant retn. BG-II	-.0197 ± .0074	-.0213 ± .0114	-.0161 ± .0168	-.0279 ± .0140	-.0068 ± .0263	-.0323 ± .0133
Filtrate BG-VII	-.0375 ± .0684	-.0469 ± .0405	-.0212 ± .0660	-.0525 ± .1060	-.0316 ± .0873	-.0301 ± .1084
<u>Gloeocapsa alpicola</u>						
Mid-log inoc. BG-I	-.0688 ± .0212	-.1356 ± .0357	-.0849 ± .0246	-.1205 ± .0980	-.0484 ± .0157	-.0466 ± .0301
Contaminant retn. BG-I	-.0194 ± .0159	-.0606 ± .0075	-.0802 ± .0516	-.0462 ± .0217	-.0484 ± .0157	-.0466 ± .0301
Day-0 inoc. BG-II	-.0868 ± .0328	-.0838 ± .0278	-.0494 ± .0176	-.0794 ± .0438	-.0781 ± .0272	-.0596 ± .0179
Contaminant retn. BG-II	-.0110 ± .0130	-.0198 ± .0117	-.0271 ± .0265	-.0139 ± .0104	-.0141 ± .0130	-.0213 ± .0111
Filtrate BG-VII	-.0395 ± .0437	-.0596 ± .0118	-.0656 ± .0082	-.0473 ± .0309	-.0197 ± .0460	-.0208 ± .2174
<u>Oscillatoria chalybia</u>						
Mid-log inoc. BG-I	-.0966 ± .0386	-.0637 ± .0518	-.1255 ± .0478	-.1153 ± .0199	-.1149 ± .0288	-.0607 ± .0108
Contaminant retn. BG-I	-.0704 ± .0311	-.0341 ± .0121	-.0393 ± .1598	-.0468 ± .0353	-.0234 ± .0272	-.0285 ± .0226
Day-0 inoc. BG-II	-.0761 ± .0327	-.0571 ± .0154	-.1986 ± .0631	-.1074 ± .0450	-.0614 ± .0181	-.0905 ± .0272
Contaminant retn. BG-II	-.0110 ± .0052	-.0138 ± .0066	-.0143 ± .0087	-.0037 ± .0165	-.0006 ± .0112	-.0047 ± .0130
Filtrate BG-VII	-.0996 ± .1473	-.0963 ± .1387	-.1012 ± .2162	-.0949 ± .1623	-.0847 ± .0721	-.0805 ± .2214

Table 3-1 Continued

Series	<i>Alcaligenes faecalis</i> *	<i>Enterobacter aerogenes</i> *	<i>Escherichia coli</i> *	<i>Proteus vulgaris</i> *	<i>Pseudomonas aeruginosa</i> *	<i>Serratia marcescens</i> *
<i>Oscillatoria formosa</i>						
Mid-log inoc. BG-I	-.1546 ± .0224	-.0910 ± .0450	-.0864 ± .0393	-.0964 ± .0507	-.0795 ± .0379	-.0679 ± .0159
Contaminant redn. BG-I	-.0410 ± .0139	-.0278 ± .0191	-.0182 ± .0194	-.0250 ± .0272	-.0428 ± .0219	-.0451 ± .0309
Day-O inoc. BG-II	-.2957 ± .2187	-.2218 ± .5164	-.2275 ± .0640	-.2231 ± .1002	-.0751 ± .0260	-.0709 ± .0165
Contaminant redn. BG-II	-.0018 ± .0139	-.0051 ± .0158	-.0120 ± .0132	-.0124 ± .0044	-.0058 ± .0101	-.0129 ± .0352
Filtrate BG-VII	-.0761 ± .3122	-.0732 ± .1638	.0136 ± .0965	-.0678 ± .1897	-.0568 ± .0728	-.0671 ± .2056
<i>Phormidium faveolarum</i>						
Mid-log inoc. BG-I	-.0880 ± .0431	-.0640 ± .0460	-.0966 ± .0599	-.1782 ± .0757	-.1378 ± .0348	-.0999 ± .1055
Contaminant redn. BG-I	.0029 ± .0142	-.0368 ± .0216	-.0196 ± .0137	-.0266 ± .0347	-.0188 ± .0084	-.0515 ± .0308
Day-O inoc. BG-II	-.0880 ± .0275	-.0594 ± .0367	-.0552 ± .0313	-.1567 ± .1194	-.2437 ± .0778	-.0456 ± .0254
Contaminant redn. BG-II	-.0195 ± .0630	-.0174 ± .0189	-.0262 ± .0235	-.0142 ± .0247	-.0047 ± .0085	-.0542 ± .2044
Filtrate BG-VII	-.0697 ± .1664	-.0841 ± .1405	-.0646 ± .2584	-.0643 ± .0767	-.0704 ± .1549	-.0811 ± .1332
<i>Ankistrodesmus braunii</i>						
Mid-log inoc. G-I	-.0701 ± .0193	-.0764 ± .0172	-.0365 ± .0290	-.0756 ± .0288	-.1129 ± .0504	-.0620 ± .0438
Day-O inoc. G-II	-.0857 ± .0435	-.0801 ± .1205	-.0542 ± .1598	-.0745 ± .3424	-.1977 ± .0297	-.1753 ± .0254
Filtrate G-VII	-.0769 ± .2780	-.0965 ± .1696	-.0520 ± .0090	-.0904 ± .0590	-.0890 ± .0751	-.0558 ± .1196
<i>Chlorella pyrenoidosa</i>						
Mid-log inoc. G-I	-.1586 ± .0219	-.1013 ± .0781	-.0624 ± .0305	-.1800 ± .1094	-.0985 ± .0767	-.0855 ± .0481
Day-O inoc. G-II	-.0743 ± .0942	-.1265 ± .0148	-.0763 ± .1384	-.0552 ± .0419	-.0574 ± .1100	-.0552 ± .0787
Filtrate G-VII	-.0925 ± .2509	-.0851 ± .2041	-.0708 ± .3320	-.0830 ± .2321	-.0550 ± .3776	-.0686 ± .3630
<i>Chlorella vulgaris</i>						
Mid-log inoc. G-I	-.1255 ± .1253	-.0949 ± .0858	-.0464 ± .0480	-.1826 ± .4619	-.1092 ± .0581	-.0651 ± .0547
Day-O inoc. G-II	-.1003 ± .0137	-.1138 ± .0155	-.0407 ± .1286	-.1352 ± .0176	-.1901 ± .0171	-.0989 ± .0148
Filtrate G-VII	-.0852 ± .1884	-.0656 ± .1201	-.0553 ± .1392	-.0757 ± .1238	-.0683 ± .2253	-.0644 ± .2491

Table 3-1 Continued

Series	<u>Alcaligenes</u> <u>faecalis</u> *	<u>Enterobacter</u> <u>aerogenes</u> *	<u>Escherichia</u> <u>coli</u> *	<u>Proteus</u> <u>vulgaris</u> *	<u>Pseudomonas</u> <u>aeruginosa</u> *	<u>Serratia</u> <u>marcescens</u> *
<u>Scenedesmus obliquus</u>						
Mid-log inoc. G-I	-.0458 ± .0365	-.0574 ± .0238	-.0583 ± .0215	-.0891 ± .0506	-.0777 ± .0357	-.0974 ± .0354
Day-O inoc. G-II	-.0655 ± .0142	-.0792 ± .0065	-.0541 ± .0631	-.0629 ± .0093	-.0466 ± .2023	-.0492 ± .1126
Filtrate G-VII	-.0324 ± .0214	-.0508 ± .0307	-.0401 ± .0352	-.0151 ± .0809	-.0550 ± .0852	-.0325 ± .0908
Mixed blue-greens, single bacteria						
inoc. BG-VIII	-.2463 ± .3895	-.2368 ± .5988	-.1666 ± .1590	-.2392 ± .6491	-.1730 ± .1538	-.1479 ± .2096
Mixed blue-greens, mixed bacteria						
inoc. BG-IX	-.2600 ± .4379	-.2741 ± .7115	-.1081 ± 2.433	-.1632 ± .4947	-.1536 ± .1237	-.1397 ± .0671
Mixed greens, single bacteria						
inoc. G-VIII	-.1635 ± .0689	-.1462 ± .0353	-.1290 ± .0773	-.1912 ± .4282	-.1744 ± .0601	-.1493 ± .0567
Mixed greens, mixed bacteria						
inoc. G-IX	-.1176 ± .3440	-.2082 ± .2771	-.1417 ± .1001	-.1743 ± .5893	-.1493 ± .1280	-.1579 ± .0885
<u>Brevibacterium sp.</u> , effect on dieoff of ...	-.0513 ± .0300	-.0494 ± .0127	-.0755 ± .0123	-.0951 ± .0178	-.1011 ± .0407	-.0624 ± .0168
<u>Flavobacterium sp.</u> , effect on dieoff of ...	-.1437 ± .0945	-.1616 ± .0743	-.0947 ± .0431	-.1520 ± .0306	-.1042 ± .0519	-.0666 ± .0333
Bacteria alone, dieoff in algal growth medium, VI	-.0228 ± .0279	-.0097 ± .0317	-.0214 ± .0263	-.0149 ± .0325	-.0133 ± .0222	-.0096 ± .0283
Bacteria alone, anaerobic dieoff rates of ...	-.0131 ± .0253	-.0352 ± .0175	-.0490 ± .0072	-.0131 ± .0307	-.0315 ± .0259	-.0563 ± .0108

Table 3-1 Continued

Series	<u>Alcaligenes</u> <u>faecalis*</u>	<u>Enterobacter</u> <u>aerogenes*</u>	<u>Escherichia</u> <u>coli*</u>	<u>Proteus</u> <u>vulgaris*</u>	<u>Pseudomonas</u> <u>aeruginosa*</u>	<u>Serratia</u> <u>marcescens*</u>
Growth rates during Series I						
<u>Anabaena cylindrica</u> Control .0130 + .0021	.0117 ± .0099	.0107 ± .0079	.0043 ± .0139	.0114 ± .0143	.0155 ± .0101	.0152 ± .0093
<u>Anacystis nidulans</u> Control .0171 + .0111	.0116 ± .0148	.0112 ± .0101	.0131 ± .0034	.0064 ± .0083	.0102 ± .0173	.0113 ± .0095
<u>Gloeocapsa alpicola</u> Control .0041 + .0071	.0083 ± .0128	.0070 ± .0072	.0085 ± .0076	.0039 ± .0109	.0049 ± .0050	.0119 ± .0060
<u>Oscillatoria chalybia</u> Control .0121 + .0021	.0084 ± .0059	.0067 ± .0048	.0049 ± .0123	.0189 ± .0078	.0155 ± .0101	.0152 ± .0093
<u>Oscillatoria formosa</u> Control .0290 + .0077	.0285 ± .0174	.0256 ± .0115	.0209 ± .0146	.0160 ± .0197	.0101 ± .0176	.0159 ± .0187
<u>Phormidium faveolarum</u> Control .0025 + .0018	.0013 ± .0116	.0005 ± .0094	.0027 ± .0088	.0048 ± .0148	.0019 ± .0118	.0059 ± .0119
<u>Ankistrodesmus braunii</u> Control .0085 + .0021	.0074 ± .0051	.0042 ± .0061	.0087 ± .0071	.0027 ± .0031	.0049 ± .0008	.0111 ± .0029
<u>Chlorella pyrenoidosa</u> Control .0199 + .0121	.0143 ± .0091	.0171 ± .0061	.0171 ± .0091	.0199 ± .0210	.0100 ± .0067	.0121 ± .0077
<u>Chlorella vulgaris</u> Control .0102 + .0037	.0177 ± .0041	.0120 ± .0141	.0200 ± .0040	.0099 ± .0061	.0154 ± .0071	.0136 ± .0088
<u>Scenedesmus obliquus</u> Control .0075 + .0065	.0071 ± .0091	.0089 ± .0072	.0101 ± .0214	.0116 ± .0100	.0171 ± .0065	.0144 ± .0061

*log₁₀ day⁻¹

Additional data on dieoff effects of enteric bacteria were obtained using a typical soil inhabitant blue-green algal species, Nostoc muscorum. Filtrate from an actively growing axenic culture of this organism was exposed to the enteric bacteria in the same manner as the other filtrate series. Since Nostoc is not ordinarily found as a phytoplankton member in waste stabilization ponds, all of the series of combinations were not run on this organism. The data for the filtrate run with Nostoc (Appendix A, Table A-50) are included and intended for comparison with the data for the other enteric bacterial-algal runs. The coefficients were: Alcaligenes, $-.0862 \pm .2171 \text{ day}^{-1}$; Enterobacter, $-.1021 \pm .1180 \text{ day}^{-1}$; Escherichia, $-.0881 \pm .1177 \text{ day}^{-1}$; Proteus, $-.1021 \pm .0078 \text{ day}^{-1}$; Pseudomonas, $-.0639 \pm .1352 \text{ day}^{-1}$; Serratia, $-.6020 \pm .0953 \text{ day}^{-1}$. These are comparatively higher rates than those obtained for many of the filtrate runs involving the other six species of blue-greens. The most pronounced effect on any bacteria by Nostoc was that exerted on Serratia. This bacteria appeared to be more resistant as compared to the other species, yet the coefficient was $-0.602 \pm .0953 \text{ day}^{-1}$.

Few genera were found to be persistent contaminants of the blue-green algal cultures. Brevibacterium and Flaveobacterium were the two most frequent contaminants, occurring primarily in filamentous blue-green species. Coefficients for these two bacterial genera in control runs of the test blue-green algae are shown in Table A-25, Appendix A. When enteric bacteria were present, definite inhibitory effects were noted in the coefficients for the culture contaminants (Table 3-1). At the same time, pronounced antagonistic effects of the enteric bacteria were noted, exerted by the contaminants. Coefficients were higher when the enterics were in the presence of Flaveobacterium as compared to Brevibacterium. Coefficients for enteric dieoffs were higher when in the presence of Flaveobacterium alone than when in the presence of many of the axenic algal cultures, further evidence that blue-green protoplasmic constituents were furnishing nutritional compounds to the enteric bacteria.

A comparison of these coefficients with those obtained when the enteric bacteria were placed in the sterile algal growth medium (Series VI control) is noteworthy because of the differences which occurred as a result of any

biological antagonism. Dieoff of enteric bacteria in algal growth medium under anaerobic and aerobic conditions was similar, for the most part, to dieoff when the enterics were present with the algae (Series BG-I, BG-II). Considering the trace quantities of nutritive organics which were present in the algal growth medium, those data demonstrate the persistent nature of the enteric bacteria and their ability to survive in situations which would be considered inadequate for life support of the bacteria.

Of the four species of green algae studied, Chlorella pyrenoidosa and C. vulgaris exerted more antagonism than did Scenedesmus obliquus or Ankistrodesmus braunii. Approximately similar dieoff rates for the enteric bacteria occurred when in the presence of Scenedesmus obliquus and Ankistrodesmus braunii and all the blue-green algae tested. Possibly Chlorella produced some substance such as chlorellin which was responsible for the accelerated dieoff of the enterics. Numerically larger coefficients were obtained for the series employing filtrate from the green algae (G-VII). Most of these coefficients were higher than those developed by the blue-green algae under similar circumstances.

Perhaps the most significant runs were those incorporating mixed algae and the additions of single bacterial and mixed bacterial species. The resulting coefficients are shown in Table 3-1. Competition among algal species for survival apparently accelerated the dieoff of the bacteria. Coefficients calculated for the individual bacterial species were similar to the rates for the same individual bacterial species when in mixed culture (comparing BG-VIII and BG-IX; G-VIII and G-IX). Oddly enough, in these series a significant number of the coefficients were higher for the mixed blue-green species than for the mixed green species. These data infer that the blue-green algae secreted antibacterial substances when in the presence of other blue-greens, whereas the green algae tested secreted their antibacterial materials in heterogeneous populations or in axenic culture. No runs were conducted with green algal contaminants due to their near total absence from the cultures of green algae. For the mixed enterics with mixed blue-green algae and separately with mixed green algae, coefficients were computed for the total numbers of enterics present. The data are as follows: mixed

blue-greens and enterics, $-0.1536 \pm .0990 \text{ day}^{-1}$; mixed green algal species and enterics, $-.1487 \pm .0935 \text{ day}^{-1}$. These coefficients would correspond to what is ordinarily considered to be a "total coliform" count dieoff coefficient.

Only a small but significant part of the total research effort was devoted to establishing the effects of the presence of enteric bacteria with algae. Biomass of controls (axenic algal cultures) were compared with samples taken during Series I runs. Coefficients representing these effects are presented last in Table 3-1. In some instances, the presence of the enteric bacteria effected a reduction in the total biomass productivity of the test algal species.

Pathogenic Bacteria Dieoff Studies

Five species of pathogenic bacteria were subjected to tests which were similar to those involving the enteric bacteria. The dieoff coefficients for those series are presented in Table 3-2 and Tables A-58 through A-72, Appendix A. Considering the difficulty encountered in maintaining those pure cultures of pathogens in the laboratory, their dieoff was slower when in the presence of algae; however, no aftergrowth was found for any of those bacterial species. Considering the coefficients in Table 3-2, it would appear that the blue-green and green algal test species had approximately the same effect on those bacteria as they did on the enteric species. Surprisingly, the mixed algal cultures did not exert as great an effect on the dieoff coefficients of the pathogens as on those of the enteric bacteria. Coefficients produced under anaerobic conditions were significantly lower than the rates in the same medium under aerobic conditions. Therefore it may be concluded that the algae had little effect on the pathogenic bacterial species.

Aftergrowth Potential Measurements

Extending the duration of the runs involving the test bacteria permitted evaluation of one of the original purposes for this investigation; namely, identification of any aftergrowth potentials of each bacterial species tested. Of the eleven species of bacteria tested, three demonstrated abilities to regenerate their populations. These were Serratia marcescens, Pseudomonas aeruginosa, and less frequently, Escherichia coli. The other enteric bacterial species as well as the pathogens apparently did not possess this

Table 3-2. Dieoff Coefficients for Series Utilizing Pathogenic Bacterial Species.

Series	<u>Salmonella</u> <u>paratyphi</u> *	<u>Salmonella</u> <u>typhosa</u> *	<u>Shigella</u> <u>paradysenteriae</u> *	<u>Shigella</u> <u>dysenteriae</u> *	<u>Vibrio</u> <u>comma</u> *
Mid-log inoculation of ...					
<u>Anabaena cylindrica</u>	-.0751 ± .0098	-.0601 ± .0351	-.0707 ± .0141	-.0742 ± .0139	-.0511 ± .0137
<u>Anacystis nidulans</u>	-.0840 ± .0174	-.0758 ± .0157	-.0981 ± .0317	-.1249 ± .0208	-.0997 ± .0247
<u>Gloeocapsa alpicola</u>	-.0657 ± .0401	-.0609 ± .0156	-.0832 ± .0087	-.0745 ± .0091	-.0755 ± .0329
<u>Oscillatoria chalybia</u>	-.0613 ± .0309	-.0523 ± .0303	-.0673 ± .0330	-.0717 ± .0178	-.0639 ± .0082
<u>Oscillatoria formosa</u>	-.0839 ± .0199	-.0684 ± .0093	-.0622 ± .0071	-.0688 ± .0217	-.0706 ± .0149
<u>Phormidium faveolarum</u>	-.0790 ± .0106	-.0602 ± .0195	-.0791 ± .0181	-.0670 ± .0186	-.0658 ± .0166
<u>Ankistrodesmus braunii</u>	-.0726 ± .0193	-.0658 ± .0181	-.0730 ± .0250	-.0707 ± .0272	-.0593 ± .0146
<u>Chlorella pyrenoidosa</u>	-.0950 ± .0495	-.0986 ± .0386	-.0996 ± .0261	-.0840 ± .0520	-.0747 ± .0383
<u>Chlorella vulgaris</u>	-.0669 ± .0334	-.0572 ± .0317	-.0633 ± .0322	-.0700 ± .0261	-.0465 ± .0283
<u>Scenedesmus obliquus</u>	-.0833 ± .0276	-.0700 ± .0381	-.1061 ± .0411	-.0935 ± .0440	-.0872 ± .0480
Mixed blue-green species	-.0759 ± .0259	-.0775 ± .0244	-.0564 ± .0187	-.1124 ± .0673	-.0933 ± .0272
Mixed green species	-.1553 ± .0617	-.1156 ± .0402	-.1702 ± .0586	-.1345 ± .0457	-.1460 ± .0535
Dieoff rates in algal growth medium, Aerobic	-.0622 ± .0454	-.0775 ± .0174	-.0738 ± .0276	-.0728 ± .0256	-.0625 ± .0204
Dieoff rates in algal growth medium, Anaerobic	-.0207 ± .0293	-.0268 ± .0262	-.0492 ± .0146	-.0194 ± .0346	-.0162 ± .0211

*log₁₀ day⁻¹

capability under the conditions of testing during these experiments. Data for the aftergrowth, and times of occurrences in the test periods are presented in Table 3-3. Aftergrowth was caused by the readily available protoplasmic constituents of the algae as the algae reached their declining or log death phase. The danger of recurrence of these bacterial species which showed the aftergrowth potential is therefore present when sufficient organic nutrients are present in the surrounding aquatic environment. And further, regardless of the efficiencies of removal of any treatment process or design parameter such as waste stabilization ponds, if absolutely 100 percent kill of these bacteria is not accomplished, aftergrowth can indeed occur in the effluent receiving-waters.

Organic Carbon Production by Algae

Little is known concerning the contribution by algae to the organic carbon content of waters and the resulting effects of the organic carbon on such parameters as bacterial survival or reproduction capacities. During Series BG-I, G-I, BG-VIII, and G-VIII, measurements were made at the 90-day time period in an attempt to determine the maximum yield of total carbon and total organic carbon by the algae, or biomass present in culture. These data are presented in Table 3-4. Significant amounts of organic carbon were present in the cultures after 90-days of testing. Comparison with the controls reveals by yet another method that some inhibition by the enteric bacteria on the overall productivity of the algae occurred. The contribution by the bacteria to the organic carbon content was negligible in all cases. This can be proven due to the fact that, on the average, it takes 10^{12} bacterial cells to equal one milligram of biomass weight and the cells are obviously not totally organic carbon. Consequently, the total organic carbon values, as presented in Table 3-4, may be assumed to have been derived from the algae themselves. These levels of organic carbon represent adequate quantities for, at least, the survival of the enteric bacteria, if not multiplication of same over a period of time.

Table 3-3. Aftergrowth Characteristics of Enteric Bacterial Species with Single Species of Algae (Series I).

Algal Species	Bacterial Genera	Min. No. Bacteria in run, No/ml	Day Min. No. Occurred	Aftergrowth, Max. No/ml	Day Max. No. Occurred
<u>Anabaena cylindrica</u>	<u>Pseudomonas</u>	10,000	63	180,000	70
	<u>Serratia</u>	6,000	63	800,000	84
<u>Anacystis nidulans</u>	<u>Pseudomonas</u>	33,000	63	310,000	70
	<u>Serratia</u>	48,000	63	340,000	84
<u>Gloeocapsa alpicola</u>	<u>Serratia</u>	250	56	8,110	91
<u>Oscillatoria chalybia</u>	<u>Pseudomonas</u>	310	56	160,000	91
<u>Phormidium faveolarum</u>	<u>Escherichia</u>	<100	56	1,920	84
	<u>Pseudomonas</u>	<100	63	3,300	70
	<u>Serratia</u>	<100	42	3,320	56
<u>Ankistrodesmus braunii</u>	<u>Pseudomonas</u>	<2,000	56	280,000	91
	<u>Serratia</u>	50,400	63	542,000	91
<u>Chlorella pyrenoidosa</u>	<u>Pseudomonas</u>	1,030	77	525,000	91
	<u>Serratia</u>	286	77	38,100	91
<u>Chlorella vulgaris</u>	<u>Pseudomonas</u>	132	63	4,000	91
<u>Scenedesmus obliquus</u>	<u>Escherichia</u>	324	63	64,200	91
	<u>Pseudomonas</u>	4,600	63	60,000	91
	<u>Serratia</u>	1,290	63	41,000	91

Table 3-4. Total Carbon and Total Organic Carbon Content of Biomass After Ninety Days
(Series BG-I, G-I, BG-VIII, and G-VIII, in mg/l).

Algal Species	Bacteria Added to Algal Culture							
	<u>Alcaligenes faecalis</u>	<u>Enterobacter aerogenes</u>	<u>Escherichia coli</u>	<u>Proteus vulgaris</u>	<u>Pseudomonas aeruginosa</u>	<u>Serratia marcescens</u>	Control	
	T.C. T.O.C.	T.C. T.O.C.	T.C. T.O.C.	T.C. T.O.C.	T.C. T.O.C.	T.C. T.O.C.	T.C. T.O.C.	T.C. T.O.C.
<u>Anabaena cylindrica</u>	47 41	60 58	47 33	53 41	51 41	49 41	77 47	47 47
<u>Anacystis nidulans</u>	36 34	49 45	36 34	38 36	33 33	41 35	52 47	47 47
<u>Gloeocapsa alpicola</u>	64 56	67 58	71 66	77 62	64 60	58 53	67 67	67 67
<u>Oscillatoria chalybia</u>	128 124	79 69	64 60	56 56	62 62	86 75	65 42	42 42
<u>Oscillatoria formosa</u>	100 88	198 154	206 165	200 166	252 198	120 75	172 168	168 168
<u>Phormidium faveolarum</u>	77 73	81 73	69 69	104 77	73 71	69 69	85 82	82 82
<u>Ankistrodesmus braunii</u>	62 41	57 43	67 52	47 40	47 38	59 48	54 50	50 50
<u>Chlorella pyrenoidosa</u>	50 37	61 50	47 40	51 45	56 47	56 47	97 96	96 96
<u>Chlorella vulgaris</u>	53 41	59 43	60 51	54 50	58 49	55 39	54 33	33 33
<u>Scenedesmus obliquus</u>	60 41	62 40	61 50	51 41	53 38	57 55	51 39	39 39
Mixed Blue-greens BG-VIII	92 58	83 49	118 95	169 124	95 67	77 77	58	58 58
Mixed Greens G-VIII	65 61	67 65	137 63	61 47	130 81	94 94	75	75 75

CHAPTER 4

LABORATORY AND FIELD WASTE STABILIZATION POND STUDIES

The objective of these experiments were to establish dieoff coefficients for selected species of bacteria under conditions which would occur in operational waste stabilization ponds. Two kinds of pond systems were investigated; namely, laboratory scale units which were designed on a volume detention time basis to closely correspond to the field units, and field scale pilot units.

Laboratory Waste Stabilization Pond Studies

A diagram of the laboratory waste stabilization ponds depicting the three different design concepts is shown in Figure 4-1. Throughout the test period of approximately 60 days, supplementary data were taken on phytoplankton populations to relate their concentrations to possible effects on the bacterial populations. The procedure was as follows. A liter of domestic wastewater was added to each of Series I, II, and III daily. Series I differed from Series II and III in that Series I began the treatment cycle with a six-liter anaerobic pretreatment chamber. Also, on a daily basis, 0.5 liter of effluent from the anaerobic unit was added to each of the two following facultative units. This was followed by the addition of one liter, combined from each of the two facultative units, to the maturation pond. In Series I the volume of the facultative units was 90 liters and that of the maturation pond was 18 liters. These volumes provided detention times of 6, 90, and 18 days respectively. The maturation ponds in Series I, II, and III were similar.

Series II facultative units provided anaerobic treatment in an anaerobic trench located at the influent end of each unit. The volume of these facultative units was 84 liters. The facultative units and the maturation pond unit in Series III had the same volume as each of the similar units in Series I. In Figure 4-1 the locations of bacterial inoculation points (i) and sampling stations (numbers) are shown. Duplicated sampling station

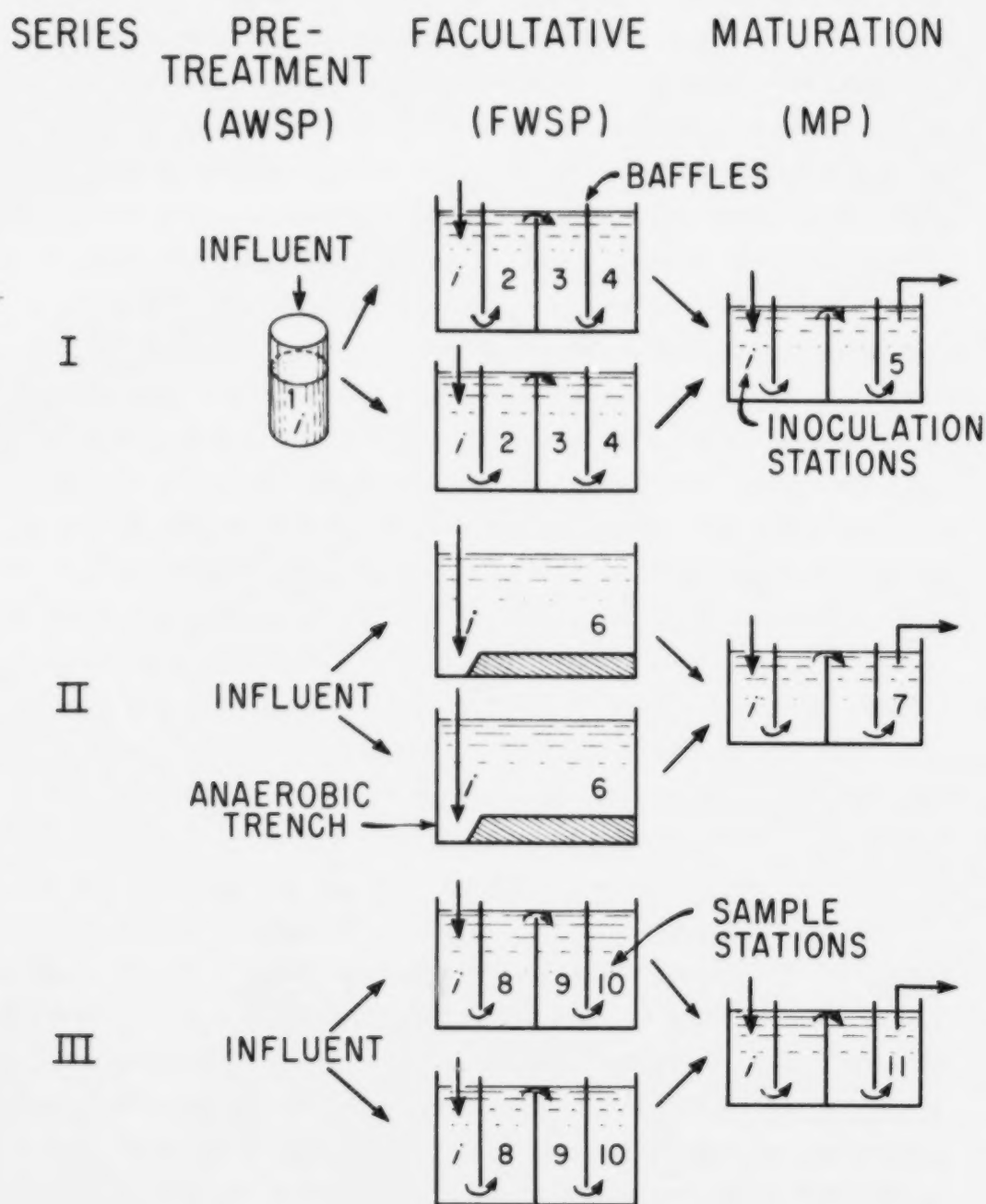


FIG. 4-1. SCHEMATIC OF LABORATORY PONDS

numbers mean that equivalent volumes were sampled at those points and mixed prior to analysis. Overall, the laboratory waste stabilization pond units proved to be amenable to bacteriological analysis because of their relatively small size, which permitted accurate bacterial inoculations.

Data for all bacteria counts were obtained by plating duplicates of two dilutions from each sample. These data, representing the statistical mean values of four counts per sample are presented in Appendix B as Tables B-1 through B-12. Blanks in these tables are the result of inconsistent plating; or the types or species of bacteria in question did not appear on the plates on that date; or the counts were too high to be statistically valid. The gaps do not imply the absence of the bacteria. Incubation periods were not consistent throughout the tests for the following reasons. In many instances it was found that room temperature incubation, as opposed to incubation at 35°C, enhanced some of the coliform species as well as other bacterial species found on the plates used for the total counts. Also, in several instances, periods of 72 hours of incubation were necessary to obtain representative counts. This peculiar characteristic of many bacterial species has been observed by the authors before. Therefore, these data provide a more accurate account of the actual numbers of bacteria present at the sampling times than would have been recorded by incubation for, say, only 24 hours at 35°C.

On July 7 and 29 cultures of Escherichia coli, Pseudomonas aeruginosa, and Serratia marcescens were inoculated into the selected locations in the laboratory units (Figure 4-1). The total bacterial numbers for each inoculum are presented in Table 4-1. By taking into account the daily additions of wastewater, its complement of the bacteria in question, volumes of the laboratory ponds and other pertinent quantitative physical factors, dieoff coefficients for each of the three added species were calculated. These coefficients are shown in Table 4-2 for the vicinities adjacent to the point of inoculation. In the majority of cases the dieoff coefficients were much higher than those found for the axenic culture experiments. The exceptions to this can be seen in the data in Table 4-2 as for, by way of example, Pseudomonas aeruginosa at station 2. Obviously, conditions prevailing

Table 4-1. Bacteria Inoculated Into Selected Stations In
Laboratory Waste Stabilization Ponds

Station*	Species and Date					
	<u>Escherichia</u>		<u>Pseudomonas</u>		<u>Serratia</u>	
	<u>coli</u>		<u>aeruginosa</u>		<u>marcescens</u>	
	July 7	July 29	July 7	July 29	July 7	July 29
1	13.2406**	9.3010	11.4700	9.9030	9.9607	9.1760
2	12.2579	13.8000	12.1847	11.6020	11.9240	11.3010
5	12.4595	9.0000	12.3180	11.6535	11.1760	9.5440
6	11.6730	11.3656	11.7136	10.0608	12.0415	--
7	13.1105	9.3980	11.8720	11.9030	12.6445	--
8	12.5841	--	11.6200	11.4775	13.4345	9.6020
11	11.2480	--	11.7780	9.7401	10.2600	11.0000

*Locations indicated in Figure 4-1.

**Log₁₀ total number inoculated.

Table 4-2. Dieoff Coefficients of Inoculated Bacteria in Laboratory Scale Waste Stabilization Ponds

Station Inoculated*	Coefficients for Bacterial Species (day ⁻¹)		
	<u>Escherichia coli</u>	<u>Pseudomonas aeruginosa</u>	<u>Serratia marcescens</u>
1	-1.03	-0.34	-0.43
2	-0.44	-0.14	-0.41
5	-0.37	-0.93	-1.38
6	-0.31	-1.00	-1.78
7	-0.61	-1.10	-1.53
8	-0.37	-0.63	-1.16
11	-0.51	-1.26	-1.15

*Inoculation point at or adjacent to indicated station; Figure 4-1.

in the early stages of the treatment units caused higher dieoff coefficients to occur than did those in the later stages. Anaerobic pretreatment did not cause the accelerated dieoff for the three inocula bacteria species, especially Pseudomonas and Serratia, as was expected. It might be concluded that the corresponding decreases in nutrient materials aided in acceleration of that dieoff which did occur. It should be noted, however, that the additions of the inocula bacteria at station 8 resulted in reduced dieoff coefficients for two of the three test species. Fewer algae were present at that station during part of the test period than were present at other stations except station 11 (Table 4-4).

The reduced phytoplanktonic concentrations throughout all runs involving the laboratory ponds in Series III appeared to be a characteristic of that series throughout the test period. Of the three test bacteria, E. coli appeared to possess the greatest capacity for survival through all three types of pond combinations. Many of the enteric bacteria remained in the final effluents. Examination of all three effluents revealed that the quality of the effluent permitted some aftergrowth of all three test bacteria species. The increases in numbers of bacteria did not exceed two orders of magnitude. However, the mere fact that aftergrowth did occur is in itself additional evidence that a much greater understanding of the behavior of these bacteria in ponds is needed.

Relationships between the bacteriological concentrations and the corresponding phytoplankton concentrations may be observed by referring to Tables 4-3 and 4-4 and Figures 4-2 through 4-5. Surprisingly few diatoms were present in any of the treatment units during the course of the study. Euglena sp. did not appear until on or slightly prior to August 20. For the purposes of this investigation the intermittent appearances of representative species of these divisions (Euglenophyta and Chrysophyta) permitted evaluation of the two divisions which were of primary concern, the blue-green algae (Cyanophyta) and the green algae (Chlorophyta).

Considering the behavior of the test species in the laboratory ponds, the following observations were made during the duration of the experiments. Periodic increases in concentrations of total bacteria, as noted for day 36

Table 4-3. Phytoplankton Found in Laboratory Waste Stabilization Ponds.

Algal Division	Date and Station Number									
	July 9					July 23				
	Station: 3		6	9		3	6	9	3	6
<u>Cyanophyta</u>	30,000*	37,000	-0-	-0-	17,000	52,000	4,000	10,700	37,200	-0-
	(23,000)**	(36,000)			(31,500)	(47,000)	(7,500)	(7,000)	(60,000)	
<u>Euglenophyta</u>	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
<u>Chrysophyta</u>	1,000	-0-	-0-	-0-	-0-	1,000	-0-	-0-	-0-	-0-
	(1,000)					(1,000)				
<u>Chlorophyta</u>	1,400	1,500	6,700	(8,000)	3,000	43,000	10,000	2,700	6,000	4,000
	(17,000)	(2,000)	(8,000)	(6,000)	(6,000)	(187,000)	(20,000)	(28,000)	(23,000)	(36,000)
<u>Total</u>	32,400	38,500	6,700	20,000	20,000	96,000	14,000	13,400	43,200	4,000
	(41,000)	(38,000)	(8,000)	(37,500)	(235,000)	(27,500)	(35,000)	(290,000)	(36,000)	

Table 4-3 Continued

Algal Division	Date and Station Number									
	August 20									
	Station: 3		6	9						
<u>Cyanophyta</u>	17,000	13,000	4,000							
	(5,000)	(144,100)	(21,500)							
<u>Euglenophyta</u>	1,000	500	100							
	(1,000)	(400)	(100)							
<u>Chrysophyta</u>	-0-	-0-	-0-							
<u>Chlorophyta</u>	10,000	19,500	6,900							
	(34,000)	(60,500)	(38,400)							
<u>Total</u>	28,000	33,000	11,000							
	(40,000)	(205,000)	(60,000)							

*Areal Standard Units of phytoplankton per ml.

**No. of phytoplankton per ml.

Table 4-4. Total Phytoplankton Concentrations Found In
Laboratory Waste Stabilization Ponds

Date	Station Number					
	3	5	6	7	9	11
July 9	32,400* (41,000)**	4,100 (12,000)	38,500 (38,000)	100 (270)	6,700 (8,000)	3,000 (6,000)
July 23	20,000 (37,500)	6,100 (11,000)	96,000 (235,000)	2,500 (3,500)	14,000 (27,500)	3,750 (13,000)
Aug. 6	13,400 (35,000)	6,300 (16,000)	43,200 (290,000)	41,900 (52,500)	4,000 (36,000)	1,670 (4,800)
Aug. 20	28,000 (40,000)	13,000 (27,500)	33,000 (205,000)	20,000 (31,500)	11,000 (60,000)	9,600 (27,000)

*Areal Standard Units of phytoplankton per ml.

** () No. phytoplankton per ml.

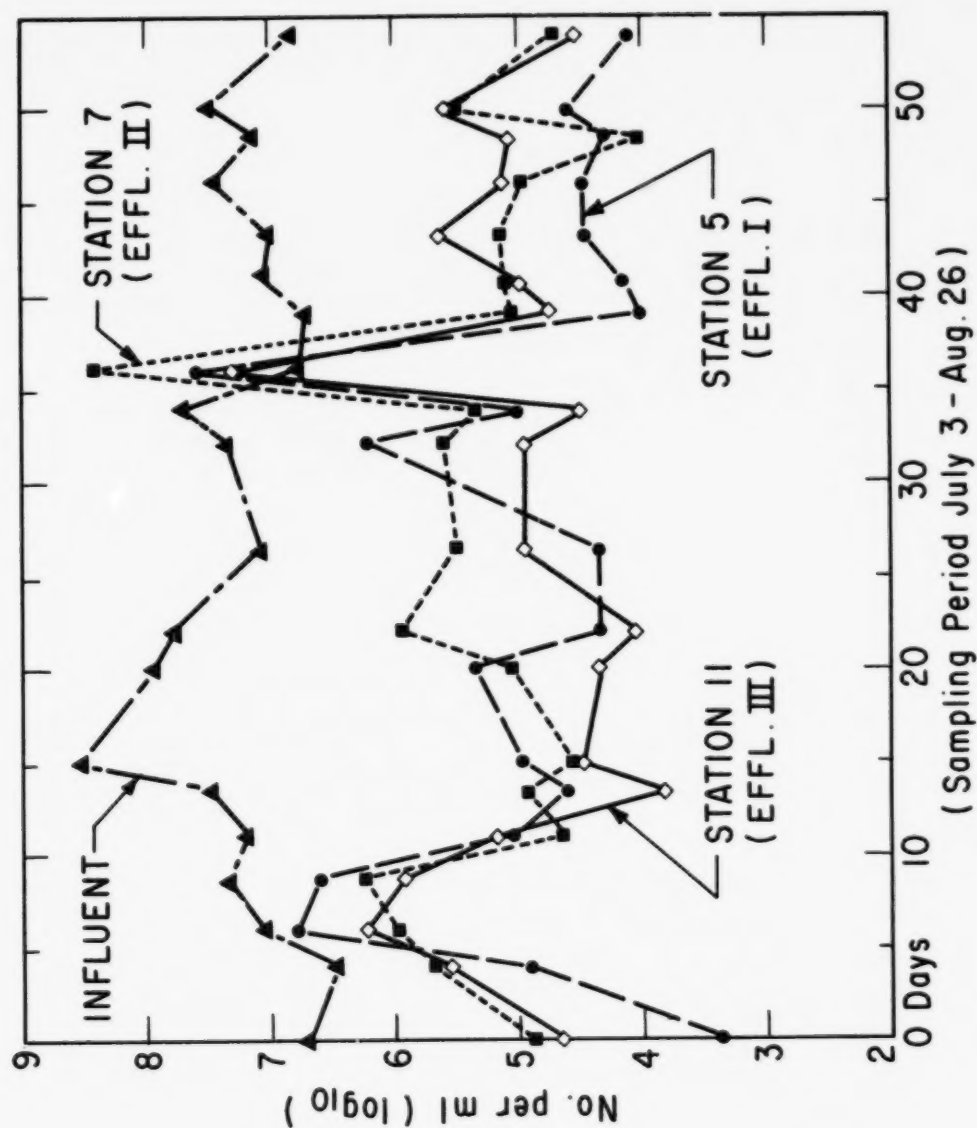


FIG. 4-2. TOTAL BACTERIA, LABORATORY PONDS

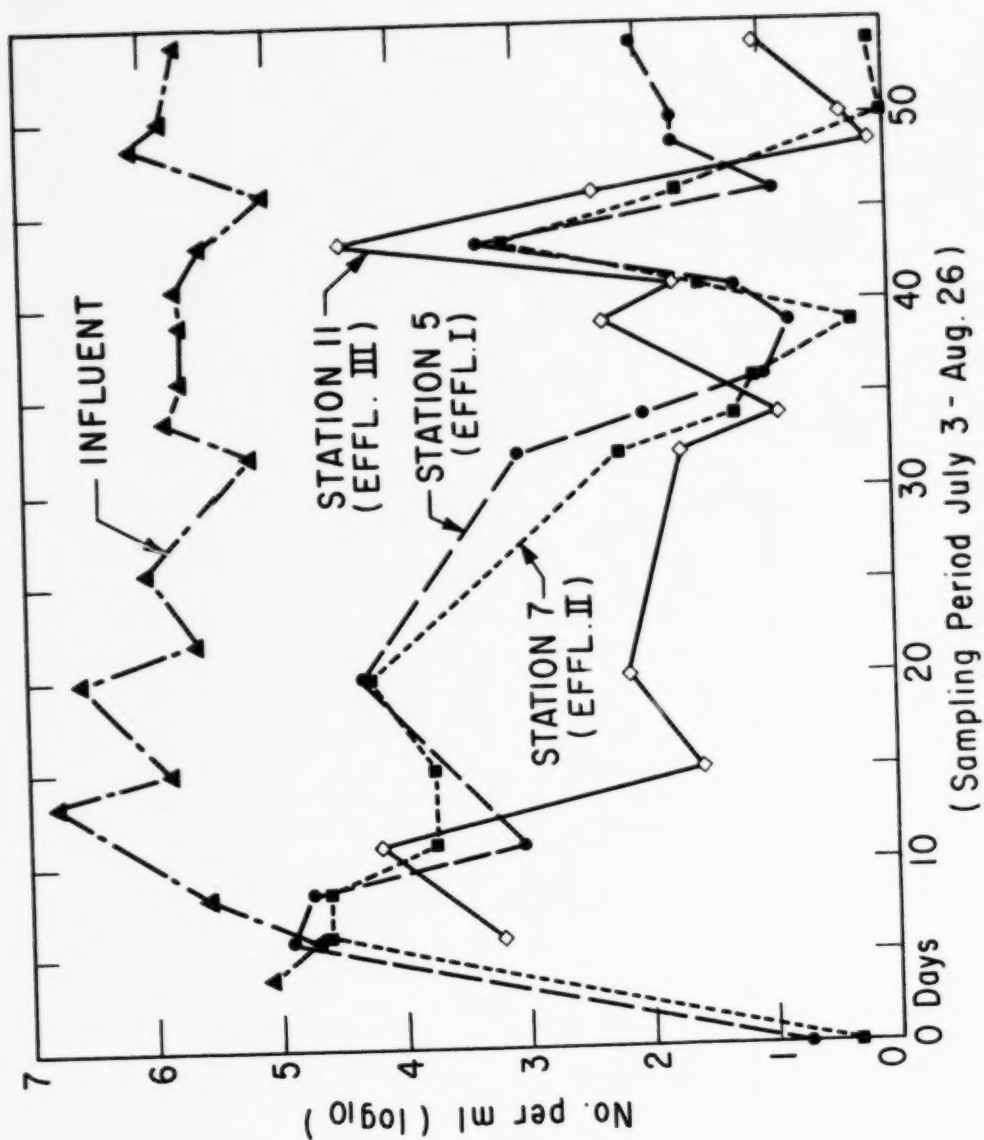


FIG. 4-3. TOTAL COLIFORM, LABORATORY PONDS

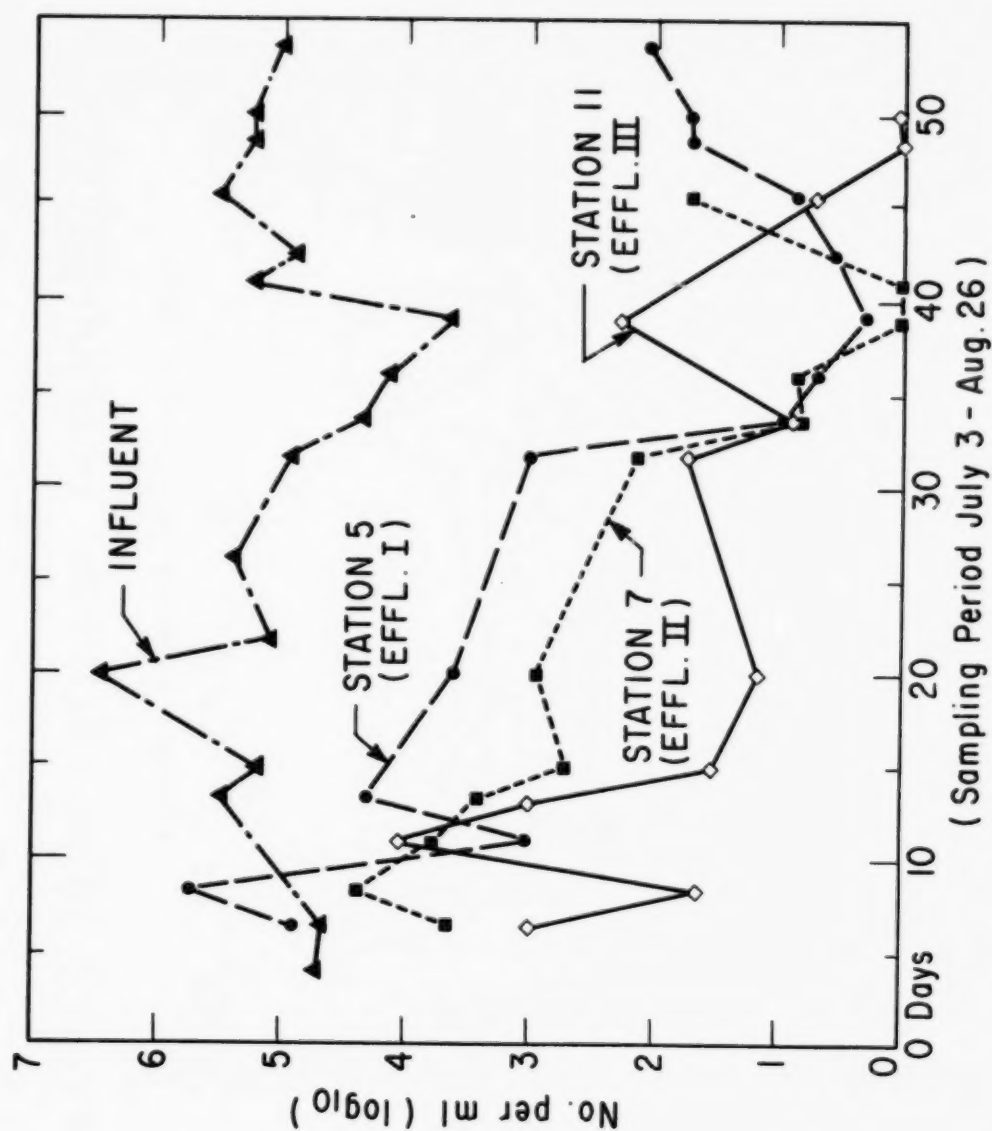


FIG. 4-4. E. coli, LABORATORY PONDS

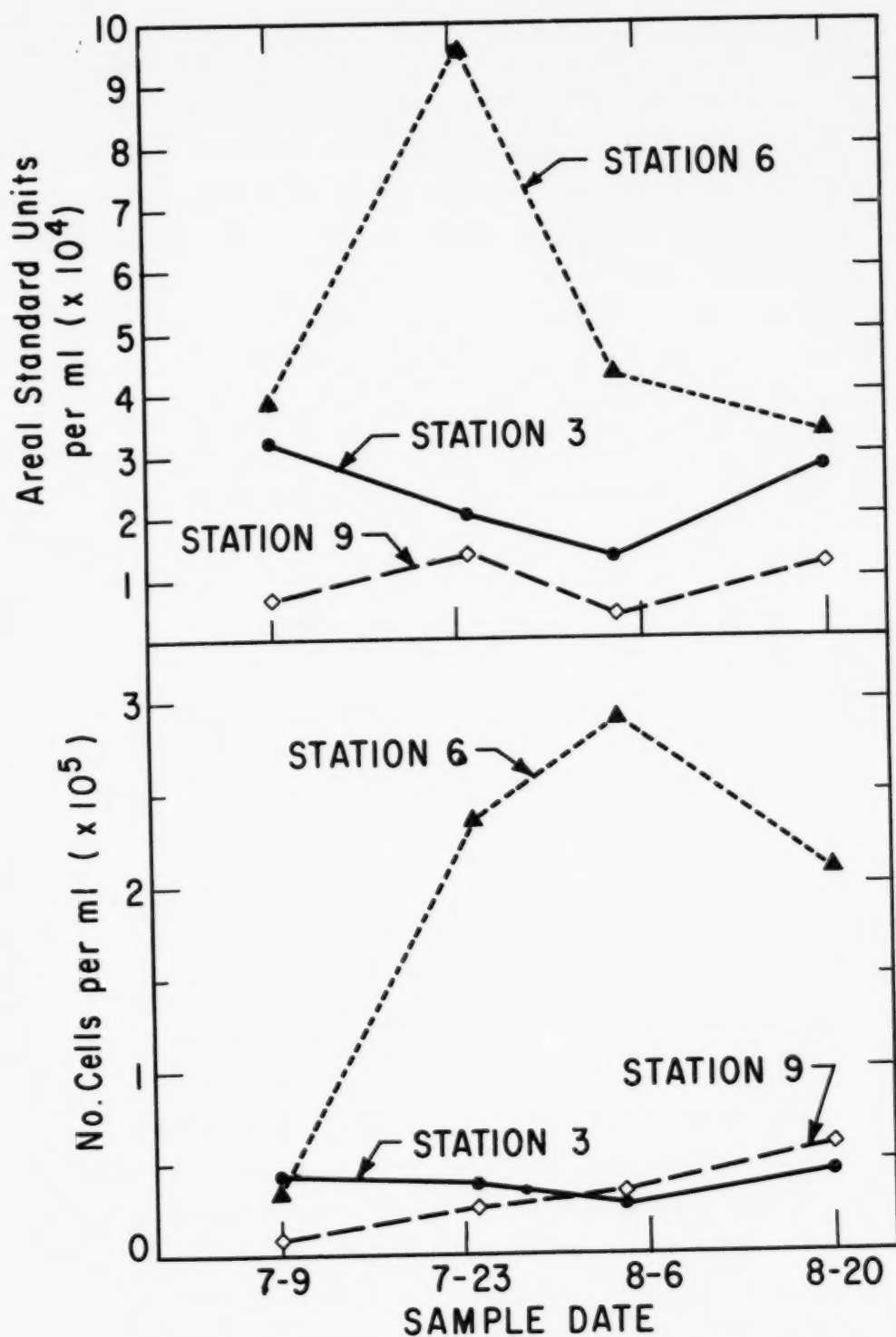


FIG. 4-5. PHYTOPLANKTON DENSITIES
IN LABORATORY PONDS

(Figures 4-2), were followed closely by a sudden increase in the total coliform count (day 44, Figure 4-3). Only a small fraction of the total coliform count was attributed to E. coli, per se. Examination of the plates for the samples in question revealed colonial morphology similar to that for Enterobacter, Alcaligenes, or Proteus, rather than Pseudomonas and Serratia. The total coliform count as well as the populations of E. coli decreased significantly on or about July 23 to about August 6 when the phytoplankton populations were relatively high. During these times the blue-green population was in the majority. Figures 4-2 through 4-4 relate other pertinent points. Acclimitization of the pond systems was occurring for approximately thirty days prior to any stabilization of the effluent quality so far as total coliform or E. coli concentrations were concerned. Statistical means were calculated for all values of effluent concentrations. These indicate the systems' overall capability in reduction of the group or species in question. Data for these follow:

	Influent	Effluent Series I (Station 5)	Effluent Series II (Station 7)	Effluent Series III (Station 11)
Total Bacteria	6.92	4.95	5.37	5.13
Total Coliform	5.87	2.36	2.34	2.02
<u>E. coli</u>	4.73	2.45	2.64	2.00
<u>Pseudomonas sp.</u>	----	3.83	3.50	3.21

The values are all $\log_{10}$ of the mean number per milliliter. Values were not calculated for Serratia because of its erratic occurrence and detectability. By the same token the presence of Pseudomonas in the influent wastewater was known and detected; however, detection by standard plate techniques was hampered due to the difficulty encountered in culturing this genus at standard laboratory incubation temperatures.

The data presented above demonstrate that pond Series I were the most efficient in reducing the total bacterial populations. The slightly increased detention time may have been a contributing factor in this reduction. For total coliform bacteria all three series exhibited similar capabilities; however, Series III exhibited slightly more efficiency in this

regard than did I or II. Similarly, Series III performed slightly more efficiently than did Series I or II in reducing E. coli numbers as well as Pseudomonas.

Escherichia coli, Pseudomonas aeruginosa, and Serratia marcescens all exhibited some survival at the three effluent sample stations 5, 7, and 11. Some correlation between the phytoplankton concentrations and the bacterial densities were observed. Pseudomonas appeared in higher numbers when reduced phytoplankton concentrations were present. E. coli apparently was capable of survival in consistently higher numbers regardless of the phytoplankton concentrations. Serratia was rarely present in consistently large concentrations in the effluents; however, the species inoculated was apparently different from that (or those) present in the wastewater. The periodic increases in Serratia (Tables B-9 and B-10, Appendix B) were observed to be associated with clumps of blue-green algae, a phenomenon which is common to all waste stabilization ponds during the summer and early fall seasons.

The group of organisms which are reported in Tables B-11 and B-12 of Appendix B, the chromogens, includes such genera as Flaveobacterium and Brevibacterium. These organisms were found to be present in wastewater in high concentrations. Very little is known about their physiology, pathogenicity (if any), or their contribution to the overall dieoff of the coliform group. From the data presented in Tables B-11 and B-12 it can be seen that aftergrowth of these bacterial genera did occur in the effluent sampling station zones 5, 7 and 11. The comparatively high numbers of these bacteria may have been responsible, at least in part, for a certain amount of the dieoff of the coliforms and/or test species. This may have occurred by either antibiosis or nutrient competition. At any rate, Flaveobacterium and Brevibacterium will require considerably more research effort before their exact contribution to waste treatment processes can be effectively evaluated.

Field Waste Stabilization Pond Studies

During and preceding the period of investigation with the laboratory waste stabilization ponds, data were obtained on three series of field waste stabilization ponds. These data were taken for a three-month period beginning on June 4 and extending through August 26. A diagram of the field ponds is shown in Figure 4-6. The laboratory waste stabilization ponds described earlier in the text were designed to approximate the detention times and types of systems of the field ponds. Series I was preceded by an anaerobic pretreatment unit which had a volume of 8,900 cubic feet and a detention time of about 4 days. The facultative pond in Series I had a volume of 117,500 cubic feet and a detention time of about 55 days. The small maturation ponds all had volumes of 18,000 cubic feet and detention times of about 8 days. Series II and III facultative ponds had volumes of 126,400 cubic feet and 126,300 cubic feet respectively with detention times of about 51 days and 59 days each. Sample stations were in the vicinities of the numbered areas of the ponds in Figure 4-6. Surface samples were taken one foot below the surface and bottom samples were taken about one foot from the bottom. This was done to avoid excessive concentrations of algae at the surface and excessive amounts of settled sludge at the bottom. Data obtained from these 12 sampling points are presented in detail in Tables B-13 through B-28, Appendix B. Objectives of this phase of the investigation were to compare the efficiencies of the three different types of waste stabilization ponds as to coliform reduction, to compare the efficiencies of the field and laboratory scale ponds, and to attempt massive inocula of selected bacteria for dieoff studies.

Inoculations with laboratory-cultured bacteria occurred on the dates indicated in Table 4-5. The numbers of bacteria which were inoculated into those ponds in certain cases proved to be ineffective as tracer methodology for dieoff studies. Dieoff of the test species was rapid in the field ponds. Calculating by volume of the ponds and daily flow rates from the influent to the sample stations indicated the following dieoff coefficients (as $\log_{10} \text{ day}^{-1}$).

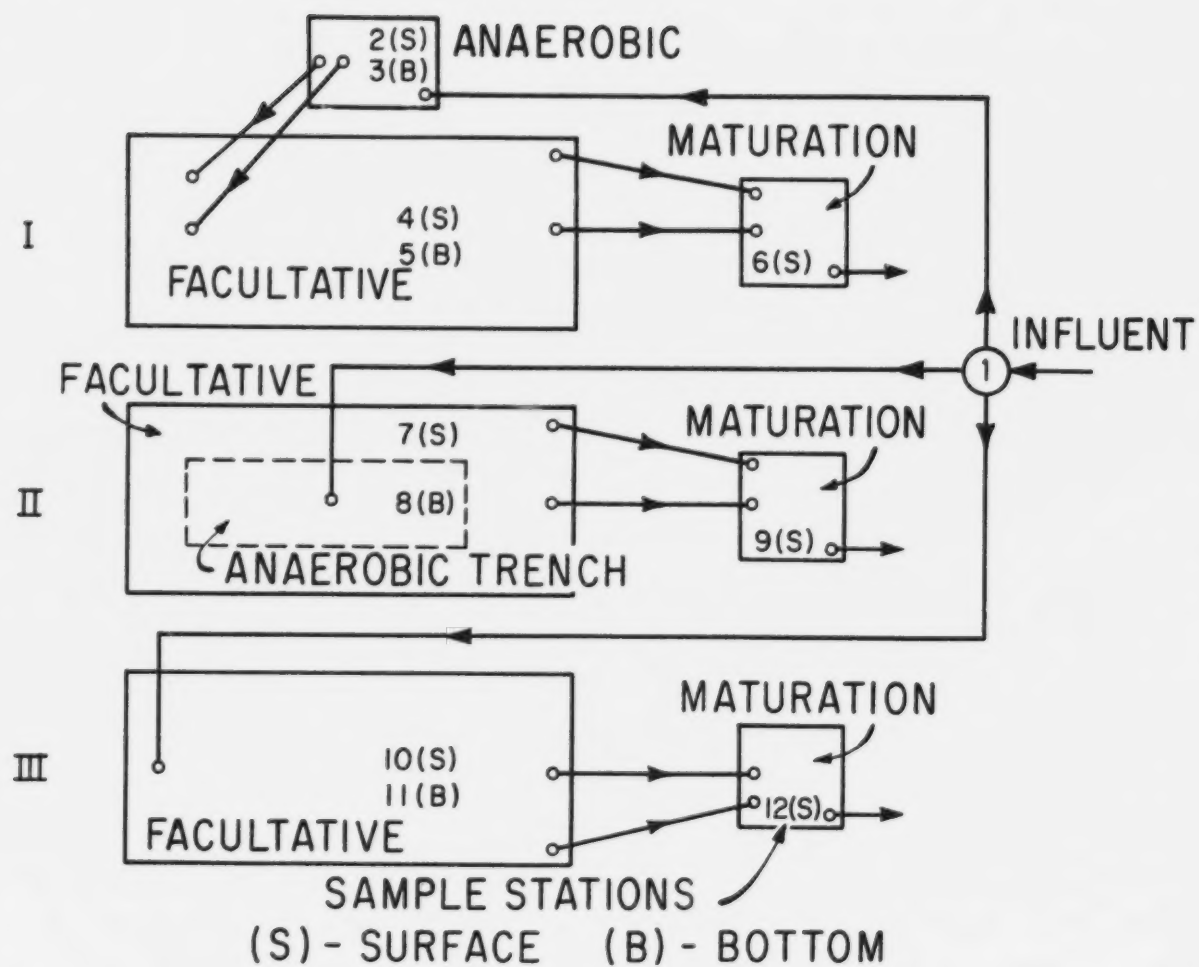


FIG. 4-6. SCHEMATIC OF WASTE STABILIZATION PONDS

Table 4-5. Bacteria Inoculated Into Selected Stations
of Waste Stabilization Ponds

Station	Date	<u>Escherichia</u> <u>coli</u>	<u>Pseudomonas</u> <u>aeruginosa</u>	<u>Serratia</u> <u>marcescens</u>
2	June 5	13.2265*	14.0592	--
4	June 5	12.9350	12.9351	--
4	June 16	13.7164	14.2812	14.1763
7	June 19	13.9235	14.0214	13.9855
7	July 29	15.0281	15.1146	14.4340
10	June 23	13.4510	14.1565	14.5513
10	July 21	14.0720	14.5761	14.2140

*log₁₀ numbers per ml.

Bacterial Species	Sample Stations		
	#4	#7	#10
<u>Escherichia coli</u>	-1.42	-1.67	-1.21
<u>Pseudomonas aeruginosa</u>	-0.89	-1.10	-0.91
<u>Serratia marcescens</u>	-1.81	-2.02	-.199

These coefficients were, without exception, higher than those found for the laboratory scale ponds, indicating accelerated antibiotic activities. Solar radiation contributed to some extent to those accelerated rates. Data for total bacteria, total coliform bacteria, and phytoplankton populations are shown in Figures 4-7 through 4-9, and Tables 4-6 and 4-7. Those data indicate, as in the case of the laboratory waste stabilization pond studies, that a period of acclimatization was occurring for approximately half the test period of three months. Means of total bacteria, total coliform bacteria and E. coli concentrations were calculated for the raw influent (station 1) and the three effluents for the test period. They were as follows (as $\log_{10}$ No./ml).

	Influent	Series I Station 6	Series II Station 9	Series III Station 12
Total Bacteria	7.14	5.04	4.91	5.25
Total Coliform	5.83	1.35	1.31	1.37
<u>E. coli</u>	5.26	0.34	0.78	0.57

These values indicate that reduction of the total bacteria was not as efficient as could be hoped for. Total coliform bacteria were reduced significantly, with the majority of reduction being due to the dieoff of E. coli, per se.

Algae which were present in the ponds throughout the test period were predominantly blue-green and green algae, as was the case for the laboratory waste stabilization ponds. Surprisingly high concentrations of algae were found at the surface of the anaerobic pretreatment pond of Series I, contributing, no doubt, to some aerobic activity. There appeared to be a direct relationship between the high phytoplankton concentrations in August and consistently lower coliform counts. Increases in total coliform

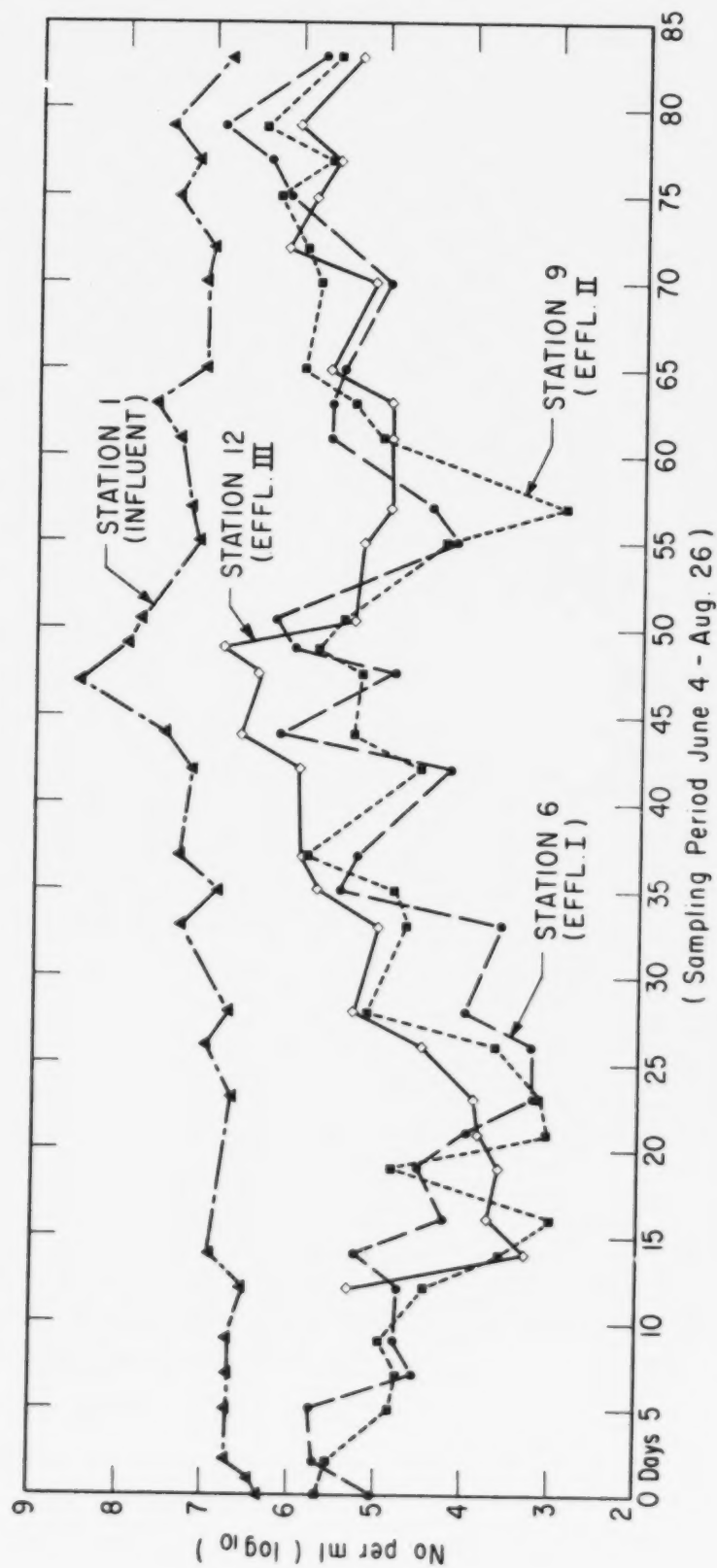


FIG. 4-7. TOTAL BACTERIA IN WASTE STABILIZATION PONDS

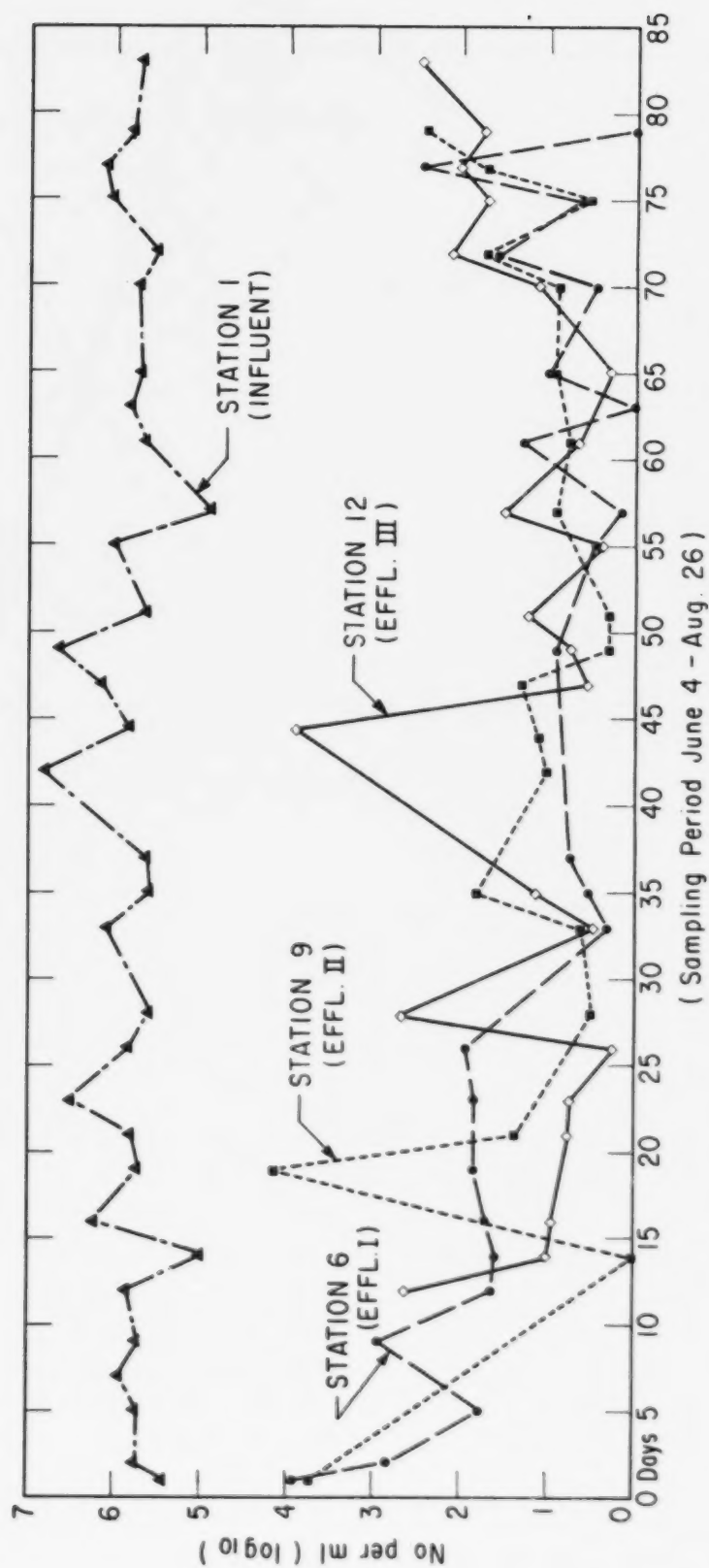


FIG. 4-8. TOTAL COLIFORM IN WASTE STABILIZATION PONDS

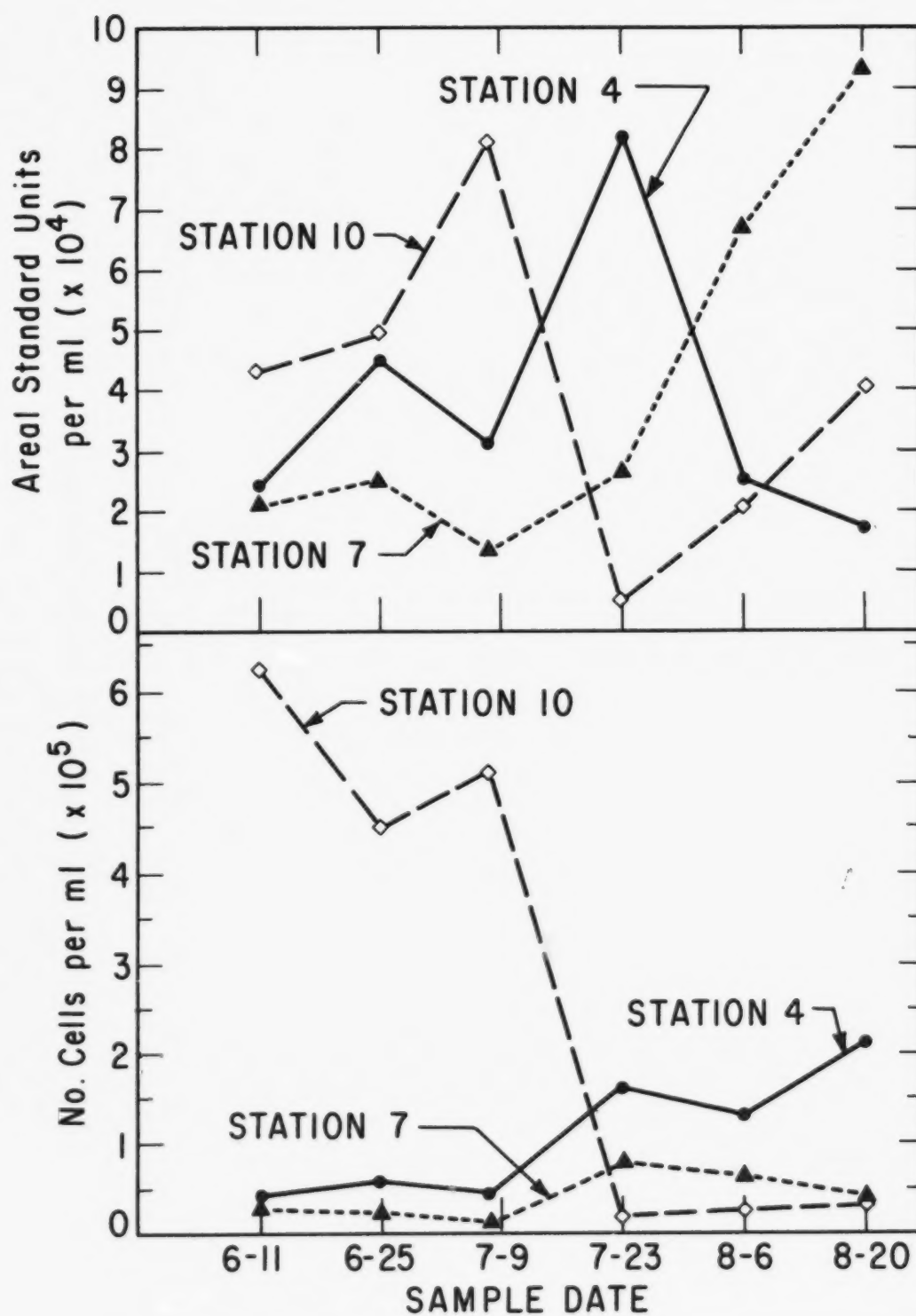


FIG. 4-9. PHYTOPLANKTON DENSITIES
IN WASTE STABILIZATION PONDS

Table 4-6. Phytoplankton Found in Waste Stabilization Ponds

Algal Division	Station: 4	Date and Station Number									
		June 11					June 25				
		7	10	4	7	10	7	10	4	7	10
Cyanophyta	5,000* (7,500)**	5,500 (4,800)	4,100 (2,500)	4,200 (8,000)	5,000 (5,000)	1,500 (4,700)	1,500 (4,700)	1,500 (4,700)	7,000 (22,000)	3,400 (3,000)	21,000 (24,500)
Euglenophyta	-0- (0-)	-0- (0-)	1,500 (1,750)	600 (650)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	4,000 (3,000)	6,000 (4,500)
Chrysophyta	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)
Chlorophyta	19,100 (42,500)	15,000 (31,200)	37,500 (612,750)	40,150 (51,350)	20,000 (22,500)	47,500 (445,300)	24,500 (27,000)	6,100 (8,000)	24,500 (27,000)	6,100 (8,000)	54,000 (488,000)
Total	24,100 (45,000)	20,500 (36,000)	43,100 (617,000)	45,000 (60,000)	25,000 (27,500)	49,000 (450,000)	31,500 (49,000)	13,500 (14,000)	31,500 (49,000)	13,500 (14,000)	81,000 (517,000)

Table 4-6 Continued

Algal Division	Station: 4	Date and Station Number									
		July 23					August 6				
		7	10	4	7	10	7	10	4	7	10
Cyanophyta	72,000 (145,000)	9,000 (17,000)	1,000 (500)	20,000 (8,000)	21,200 (10,000)	15,500 (12,000)	3,000 (2,000)	82,000 (17,000)	3,000 (2,000)	82,000 (17,000)	-0- (0-)
Euglenophyta	-0- (0-)	-0- (0-)	-0- (0-)	1,000 (1,000)	1,500 (1,200)	250 (100)	2,000 (1,000)	-0- (0-)	2,000 (1,000)	-0- (0-)	-0- (0-)
Chrysophyta	-0- (0-)	900 (1,000)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)	-0- (0-)
Chlorophyta	9,000 (20,000)	16,000 (57,000)	3,900 (19,500)	4,000 (123,000)	44,300 (50,800)	5,250 (13,400)	13,000 (207,000)	11,000 (22,000)	13,000 (207,000)	11,000 (22,000)	40,000 (27,000)
Total	81,000 (165,000)	25,400 (75,000)	4,900 (20,000)	25,000 (132,000)	67,000 (62,000)	21,000 (25,500)	17,000 (210,000)	93,000 (39,000)	17,000 (210,000)	93,000 (39,000)	40,000 (27,000)

*Areal Standard Units of phytoplankton per ml.

**() No. of phytoplankton per ml.

Table 4-7. Phytoplankton Concentrations Found In Waste Stabilization Ponds

Date	Station Number											
	2	3	4	5	6	7	8	9	10	11	12	
June 11	1,100* (900)**	500 (400)	24,100 (45,000)	22,500 (30,000)	7,000 (13,000)	20,500 (36,000)	17,000 (22,500)	5,500 (11,000)	43,100 (617,000)	11,000 (13,500)	2,700 (3,500)	
June 25	2,100 (1,300)	250 (100)	45,000 (60,000)	30,000 (27,000)	6,500 (12,500)	25,000 (27,500)	7,900 (15,000)	4,900 (7,200)	49,000 (450,000)	6,200 (12,500)	3,850 (14,000)	
July 2	96,900 (2,001,000)	3,600 (1,009,000)	31,500 (49,000)	28,700 (55,000)	6,400 (17,000)	13,500 (14,000)	4,600 (6,000)	9,800 (23,000)	81,000 (517,000)	31,900 (555,000)	26,000 (380,000)	
July 23	16,670 (27,200)	60,000 (80,000)	81,000 (165,000)	88,000 (175,000)	66,000 (285,000)	25,900 (75,000)	2,000 (3,000)	19,700 (21,000)	4,900 (20,000)	5,000 (38,000)	7,850 (43,000)	
Aug. 6	13,700 (20,000)	7,500 (13,500)	25,000 (132,000)	22,500 (35,750)	25,500 (38,500)	67,000 (62,000)	11,500 (13,000)	21,500 (30,000)	21,000 (25,500)	13,700 (33,000)	7,000 (11,000)	
Aug. 20	17,500 (25,500)	6,500 (11,500)	17,000 (210,000)	19,500 (218,000)	40,000 (67,500)	93,000 (39,000)	21,000 (19,000)	8,100 (13,400)	40,000 (27,000)	1,000 (1,100)	14,000 (17,500)	

*Areal Standard Units of phytoplankton per ml.

**() No. of phytoplankton per ml.

counts in late August (day 70 on) corresponded closely with the comparatively lower algae counts for the period.

Survival of Pseudomonas sp. in these ponds was apparently very difficult as can be seen by the data in Tables B-22 through B-24. Some carryover and aftergrowth was evident in the maturation pond of Series III (station 12). That particular station had a bloom of Brachionus around July 17 in concentrations of up to 200 per milliliter in the surface waters. Those large numbers should have significantly reduced the bacterial population in that time period; however, no significant reduction was noted. On many occasions the concentration of coliform bacteria were lower in the deeper waters than in the surface waters. It is entirely possible that a greater amount of antibiotic activity was occurring in the deeper waters. Apparently few Serratia sp. were present in the influent wastewater. Those individuals which were present appeared to survive until reaching the facultative or maturation ponds. Some aftergrowth of this genus was observed in the maturation ponds. The chromagens exhibited very low, if any, dieoff in most instances. Their higher numbers may have contributed to the overall comparatively efficient reduction of the coliforms. It is clear that the field waste stabilization ponds were more effective in bacterial reduction than were the laboratory units, so far as the coliform group were concerned.

These investigations on the field pilot waste stabilization ponds and the laboratory ponds were accomplished in conjunction with investigations in progress under grant WTRD 178-01-68, Federal Water Pollution Control Administration, "Design Guides for Selected Wastewater Treatment Processes."

With the information presented by this investigation, remaining efforts in this important area of sanitary engineering should be directed toward establishing: (a) guidelines on amounts of disinfectant necessary to eliminate proportions of enteric bacterial populations to meet effluent specifications; and (b) cost-benefit specifications based on the as yet unknown pathogenicity of other bacterial species found in waste stabilization ponds and related wastewater treatment systems. An undeniable need exists at the present time for this information.

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APPENDIX A

STATISTICS OF ALL LABORATORY AXENIC CULTURE STUDIES

Key to Appendix A tabulated columns:

N	= number of data points used in computing that particular regression line
S_H^2	= the variance of data points about the mean of all data points
S_r^2	= the variation of data points about the regression line
S_H^2/S_r^2	= the variance ratio which if referenced against appropriate standard "F" tables would indicate the statistical validity of the data.
b	= calculated y-intercept
k	= the dieoff (-) or growth (+) rate coefficient of the typical $C_t = C_0 10^{kt}$ formulation
R	= the multiple correlation coefficient

Table A-1

Reduction statistics of enteric bacteria species with Anabaena cylindrica. Series BG-I. Bacteria added to algae when in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	57.966	0.6783	(8.7213 $\pm$.8873)	(-.0774 $\pm$.0192)	0.892
<u>Enterobacter aerogenes</u>					
12	227.04	0.2110	(8.3621 $\pm$.4949)	(-.0854 $\pm$.0107)	0.970
<u>Escherichia coli</u>					
12	35.917	0.2882	(8.0230 $\pm$.5784)	(-.0397 $\pm$.0125)	0.837
<u>Proteus vulgaris</u>					
12	79.048	0.8310	(8.3912 $\pm$.9822)	(-.1000 $\pm$.0213)	0.919
<u>Pseudomonas aeruginosa</u>					
13	17.007	0.6349	(8.2665 $\pm$.9368)	(-.0512 $\pm$.0241)	0.739
<u>Serratia marcescens</u>					
14	3.1013	1.7802	(6.8402 $\pm$ 1.5687)	(-.0366 $\pm$.0404)	0.341

Table A-2

Reduction statistics of enteric bacteria species with Anacystis nidulans. Series BG-I. Bacteria added to algae when in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	78.809	0.4033	(7.9753 $\pm$.8313)	(-.1145 $\pm$.0260)	0.940
<u>Enterobacter aerogenes</u>					
12	97.721	0.3406	(7.7923 $\pm$.7639)	(-.1172 $\pm$.0239)	0.951
<u>Escherichia coli</u>					
12	116.24	0.3905	(8.1602 $\pm$.6598)	(-.0796 $\pm$.0137)	0.936
<u>Proteus vulgaris</u>					
12	111.76	0.3614	(7.6181 $\pm$.6798)	(-.0899 $\pm$.0161)	0.941
<u>Pseudomonas aeruginosa</u>					
13	57.109	0.2387	(7.8915 $\pm$.5883)	(-.0614 $\pm$.0158)	0.904
<u>Serratia marcescens</u>					
14	83.845	0.1375	(8.3103 $\pm$.4194)	(-.0480 $\pm$.0099)	0.923

Table A-3

Reduction statistics of enteric bacteria species with Gloeocapsa alpicola.
Series BG-I. Bacteria added to algae when in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	36.494	0.9304	(6.5049 $\pm$ 1.0184)	(-.0688 $\pm$.0212)	0.820
<u>Enterobacter aerogenes</u>					
12	79.796	0.1942	(8.1088 $\pm$.7585)	(-.1356 $\pm$.0357)	0.964
<u>Escherichia coli</u>					
12	44.764	0.5826	(7.7978 $\pm$.9192)	(-.0849 $\pm$.0246)	0.882
<u>Proteus vulgaris</u>					
12	8.3744	1.4614	(8.3445 $\pm$ 2.0807)	(-.1205 $\pm$.0980)	0.736
<u>Pseudomonas aeruginosa</u>					
13	52.261	0.1064	(7.7185 $\pm$.5751)	(-.0484 $\pm$.0157)	0.946
<u>Serratia marcescens</u>					
14	20.3386	0.1045	(8.0011 $\pm$.7897)	(-.0466 $\pm$.0301)	0.910

Table A-4

Reduction statistics of enteric bacteria species with Oscillatoria chalybia.
Series BGI. Bacteria added to algae when in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	22.511	2.0704	(6.5580 $\pm$ 1.6270)	(-.0966 $\pm$.0386)	0.763
<u>Enterobacter aerogenes</u>					
12	6.1434	1.5995	(6.1868 $\pm$ 1.6554)	(-.0637 $\pm$.0518)	0.551
<u>Escherichia coli</u>					
12	31.303	0.6905	(6.4209 $\pm$ 1.2376)	(-.1255 $\pm$.0478)	0.887
<u>Proteus vulgaris</u>					
12	136.60	0.2356	(6.9627 $\pm$.6353)	(-.1153 $\pm$.0199)	0.965
<u>Pseudomonas aeruginosa</u>					
13	64.500	0.4957	(8.4764 $\pm$.9215)	(-.1149 $\pm$.0288)	0.928
<u>Serratia marcescens</u>					
14	109.20	0.2419	(7.4993 $\pm$.5193)	(-.0607 $\pm$.0108)	0.932

Table A-5

Reduction statistics of enteric bacteria species with Oscillatoria formosa.
Series BGI. Bacteria added to algae when in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	216.93	0.1511	(8.6823 $\pm$.5790)	(-.1546 $\pm$.0224)	0.982
<u>Enterobacter aerogenes</u>					
12	14.656	3.7099	(7.3945 $\pm$ 2.0752)	(-.0910 $\pm$.0450)	0.677
<u>Escherichia coli</u>					
12	17.347	2.8252	(7.1810 $\pm$ 1.8109)	(-.0864 $\pm$.0393)	0.712
<u>Proteus vulgaris</u>					
12	12.962	4.7076	(6.5127 $\pm$ 2.3376)	(-.0964 $\pm$.0507)	0.649
<u>Pseudomonas aeruginosa</u>					
13	15.716	2.6409	(7.1070 $\pm$ 1.7509)	(-.0795 $\pm$.0379)	0.692
<u>Serratia marcescens</u>					
14	65.150	0.4653	(7.6482 $\pm$.7349)	(-.0679 $\pm$.0159)	0.903

Table A-6

Reduction statistics of enteric bacteria species with Phormidium faveolarum.
Series BGI. Bacteria added to algae when in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	14.979	3.3952	(6.9144 $\pm$ 1.9852)	(-.0880 $\pm$.0431)	0.681
<u>Enterobacter aerogenes</u>					
12	6.9355	3.8784	(5.0351 $\pm$ 2.1218)	(-.0640 $\pm$.0460)	0.498
<u>Escherichia coli</u>					
12	9.8227	3.9133	(5.0539 $\pm$ 2.3258)	(-.0966 $\pm$.0599)	0.621
<u>Proteus vulgaris</u>					
12	25.151	1.7319	(6.2764 $\pm$ 1.9600)	(-.1782 $\pm$.0757)	0.863
<u>Pseudomonas aeruginosa</u>					
13	71.313	0.3654	(7.1779 $\pm$.9003)	(-.1378 $\pm$.0348)	0.947
<u>Serratia marcescens</u>					
14	4.9669	1.6954	(6.8908 $\pm$ 2.2411)	(-.0999 $\pm$.1055)	0.623

Table A-7

Reduction statistics of bacterial contaminants of Anabaena cylindrica
during series BG-I with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	0.7611	0.3184	(9.3911 $\pm$ 1.3784)	(-.0157 $\pm$.0526)	0.276
<u>Enterobacter aerogenes</u>					
12	12.004	0.0249	(9.7528 $\pm$.3856)	(-.0175 $\pm$.0147)	0.857
<u>Escherichia coli</u>					
12	0.6891	0.1714	(9.6374 $\pm$ 2.3863)	(-.0173 $\pm$.1320)	0.408
<u>Proteus vulgaris</u>					
11	0.8337	0.0605	(9.7131 $\pm$.4338)	(-.0046 $\pm$.0118)	0.217
<u>Pseudomonas aeruginosa</u>					
12	45.860	0.0051	(9.3210 $\pm$.1736)	(-.0154 $\pm$.0066)	0.958
<u>Serratia marcescens</u>					
12	0.7622	0.0224	(9.6187 $\pm$.2641)	(-.0027 $\pm$.0072)	0.203

Table A-8

Reduction statistics of bacterial contaminants of Anacystis nidulans
during series BG-I with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	0.1918	0.3267	(8.4975 $\pm$ 1.0079)	(.0051 $\pm$.0275)	0.060
<u>Enterobacter aerogenes</u>					
12	5.2952	0.0113	(9.7894 $\pm$.2597)	(-.0078 $\pm$.0099)	0.726
<u>Escherichia coli</u>					
12	6.5719	0.0472	(9.4214 $\pm$.3833)	(-.0114 $\pm$.0105)	0.686
<u>Proteus vulgaris</u>					
12	0.8462	0.8866	(8.9210 $\pm$ 1.6604)	(-.0177 $\pm$.0453)	0.820
<u>Pseudomonas aeruginosa</u>					
12	2.0035	1.6987	(9.9329 $\pm$ 3.1842)	(-.0589 $\pm$.1216)	0.500
<u>Serratia marcescens</u>					
12	34.179	0.0150	(9.2648 $\pm$.2163)	(-.0147 $\pm$.0059)	0.919

Table A-9

Reduction statistics of bacterial contaminants of Gloeocapsa alpicola
during series BG-I with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	12.7660	0.0290	(7.6995 $\pm$.4162)	(-.0194 $\pm$.0159)	0.864
<u>Enterobacter aerogenes</u>					
12	355.73	0.0246	(8.9674 $\pm$.2769)	(-.0606 $\pm$.0075)	0.992
<u>Escherichia coli</u>					
12	20.605	0.3061	(8.2531 $\pm$ 1.3517)	(-.0802 $\pm$.0516)	0.911
<u>Proteus vulgaris</u>					
12	25.218	0.2025	(8.5118 $\pm$.7937)	(-.0462 $\pm$.0217)	0.894
<u>Pseudomonas aeruginosa</u>					
12	52.609	0.1064	(7.7185 $\pm$.5751)	(-.0484 $\pm$.0157)	0.946
<u>Serratia marcescens</u>					
12	20.338	0.1050	(8.0011 $\pm$.7897)	(-.0466 $\pm$.0301)	0.910

Table A-10

Reduction statistics of bacterial contaminants of Oscillatoria chalybia
during series BG-I with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	43.578	0.1113	(5.1798 $\pm$.8152)	(-.0704 $\pm$.0311)	0.956
<u>Enterobacter aerogenes</u>					
12	44.1414	0.0632	(5.9133 $\pm$.4432)	(-.0341 $\pm$.0121)	0.936
<u>Escherichia coli</u>					
13	0.5146	2.9367	(5.6901 $\pm$ 4.1866)	(-.0393 $\pm$.1598)	0.205
<u>Proteus vulgaris</u>					
11	9.7113	0.5394	(6.9309 $\pm$ 1.2951)	(-.0468 $\pm$.0353)	0.764
<u>Pseudomonas aeruginosa</u>					
12	6.3348	0.0851	(7.8599 $\pm$.7127)	(-.0234 $\pm$.0272)	0.760
<u>Serratia marcescens</u>					
12	13.609	0.0587	(8.8888 $\pm$.5918)	(-.0285 $\pm$.0226)	0.872

Table A-11

Reduction statistics of bacterial contaminants of Oscillatoria formosa
during series BG-I with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	48.049	0.1016	(9.6125 $\pm$.5447)	(-.0410 $\pm$.0139)	0.941
<u>Enterobacter aerogenes</u>					
12	11.688	0.1919	(9.7453 $\pm$.7484)	(-.0278 $\pm$.0191)	0.796
<u>Escherichia coli</u>					
9	4.8621	0.1967	(9.8661 $\pm$.7578)	(-.0182 $\pm$.0194)	0.618
<u>Proteus vulgaris</u>					
12	7.222	0.0850	(9.6902 $\pm$.7123)	(-.0250 $\pm$.0272)	0.783
<u>Pseudomonas aeruginosa</u>					
11	21.177	0.2511	(10.0314 $\pm$.8560)	(-.0428 $\pm$.0219)	0.876
<u>Serratia marcescens</u>					
11	18.190	0.1096	(9.7702 $\pm$.8088)	(-.0451 $\pm$.0309)	0.901

Table A-12

Reduction statistics of bacterial contaminants of Phormidium faveolarum
during series BG-I with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	0.2333	0.1059	(7.2847 $\pm$.5559)	(.0029 $\pm$.0142)	0.072
<u>Enterobacter aerogenes</u>					
12	16.099	0.2447	(9.0394 $\pm$.8451)	(-.0368 $\pm$.0216)	0.843
<u>Escherichia coli</u>					
12	11.352	0.0985	(8.7132 $\pm$.5361)	(-.0196 $\pm$.0137)	0.791
<u>Proteus vulgaris</u>					
12	3.2495	0.6308	(9.0526 $\pm$ 1.3569)	(-.0266 $\pm$.0347)	0.520
<u>Pseudomonas aeruginosa</u>					
12	27.377	0.0374	(8.7549 $\pm$.3303)	(-.0188 $\pm$.0084)	0.901
<u>Serratia marcescens</u>					
12	23.895	0.1088	(8.7565 $\pm$.8059)	(-.0515 $\pm$.0308)	0.923

Table A-13

Reduction statistics of enteric bacteria species with Anabaena cylindrica.
Series BG-II. Bacteria and algae inoculated within
twenty-four hours of one another.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
11	6.459	4.5436	(5.4092 $\pm$ 2.0979)	(-.0582 $\pm$.0419)	0.418
<u>Enterobacter aerogenes</u>					
9	7.704	4.2371	(5.6137 $\pm$ 2.2365)	(-.0816 $\pm$.0557)	0.524
<u>Escherichia coli</u>					
9	16.612	3.8936	(6.9423 $\pm$ 2.1439)	(-.1132 $\pm$.0534)	0.697
<u>Proteus vulgaris</u>					
12	16.439	3.1431	(5.6887 $\pm$ 1.6783)	(-.0687 $\pm$.0307)	0.622
<u>Pseudomonas aeruginosa</u>					
12	14.83	0.3628	(7.3219 $\pm$.5702)	(-.0702 $\pm$.0104)	0.937
<u>Serratia marcescens</u>					
12	18.062	2.0567	(5.8236 $\pm$ 1.3576)	(-.0583 $\pm$.0249)	0.644

Table A-14

Reduction statistics of enteric bacteria species with Anacystis nidulans.
Series BG-II. Bacteria and algae inoculated within
twenty-four hours of one another.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	15.144	0.9024	(6.0191 $\pm$ 1.1080)	(-.0640 $\pm$.0320)	0.716
<u>Enterobacter aerogenes</u>					
12	13.014	1.6865	(5.3492 $\pm$ 1.2294)	(-.0448 $\pm$.0225)	0.565
<u>Escherichia coli</u>					
12	52.405	0.7412	(5.6975 $\pm$.8150)	(-.0596 $\pm$.0149)	0.840
<u>Proteus vulgaris</u>					
10	4.2597	5.0709	(4.4056 $\pm$ 2.2207)	(-.0522 $\pm$.0470)	0.347
<u>Pseudomonas aeruginosa</u>					
11	40.969	0.5410	(7.0880 $\pm$.7078)	(-.0474 $\pm$.0136)	0.820
<u>Serratia marcescens</u>					
12	6.6982	3.1234	(5.7883 $\pm$ 1.6731)	(-.0437 $\pm$.0306)	0.401

Table A-15

Reduction statistics of enteric bacteria species with Gloeocapsa alpicola.
Series BG-II. Bacteria and algae inoculated within
twenty-four hours of one another.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	23.541	2.7722	(6.0652 $\pm$ 1.6387)	(-.0868 $\pm$.0328)	0.723
<u>Enterobacter aerogenes</u>					
12	30.543	1.9952	(5.5931 $\pm$ 1.3902)	(-.0838 $\pm$.0278)	0.772
<u>Escherichia coli</u>					
12	27.325	0.7285	(5.0102 $\pm$.8524)	(-.0494 $\pm$.0176)	0.773
<u>Proteus vulgaris</u>					
12	11.356	3.6999	(5.1014 $\pm$ 1.9798)	(-.0794 $\pm$.0438)	0.587
<u>Pseudomonas aeruginosa</u>					
12	27.164	2.4549	(6.4011 $\pm$ 1.4833)	(-.0781 $\pm$.0272)	0.731
<u>Serratia marcescens</u>					
12	36.312	1.0680	(5.4419 $\pm$.9783)	(-.0596 $\pm$.0179)	0.784

Table A-16

Reduction statistics of enteric bacteria species with Oscillatoria chalybia.
Series BG-II. Bacteria and algae inoculated within
twenty-four hours of one another.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	18.249	2.7641	(5.4482 $\pm$ 1.6169)	(-.0761 $\pm$.0327)	0.670
<u>Enterobacter aerogenes</u>					
12	46.006	0.6161	(5.4358 $\pm$.7633)	(-.0571 $\pm$.0154)	0.836
<u>Escherichia coli</u>					
12	44.993	0.751	(8.2274 $\pm$ 1.3374)	(-.1986 $\pm$.0631)	0.918
<u>Proteus vulgaris</u>					
12	21.521	1.7036	(5.5990 $\pm$ 1.5143)	(-.1074 $\pm$.0450)	0.782
<u>Pseudomonas aeruginosa</u>					
12	41.208	0.4405	(6.4460 $\pm$.7140)	(-.0614 $\pm$.0181)	0.855
<u>Serratia marcescens</u>					
12	38.386	1.4187	(6.7981 $\pm$ 1.2119)	(-.0905 $\pm$.0272)	0.827

Table A-17

Reduction statistics of enteric bacteria species with Oscillatoria formosa.
Series BG-II. Bacteria and algae inoculated within
twenty-four hours of one another.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	15.581	1.3746	(6.8638 $\pm$ 2.8644)	(-.2957 $\pm$.2187)	0.886
<u>Enterobacter aerogenes</u>					
12	7.3510	0.6556	(6.8156 $\pm$ 4.6670)	(-.2218 $\pm$.5164)	0.880
<u>Escherichia coli</u>					
12	69.975	0.3625	(8.0650 $\pm$ 1.0976)	(-.2275 $\pm$.0640)	0.959
<u>Proteus vulgaris</u>					
12	27.448	0.8883	(7.9273 $\pm$ 1.781)	(-.2231 $\pm$.1002)	0.901
<u>Pseudomonas aeruginosa</u>					
12	27.483	2.2444	(6.7767 $\pm$ 1.4182)	(-.0751 $\pm$.0260)	0.733
<u>Serratia marcescens</u>					
12	60.798	0.9046	(6.5623 $\pm$.9004)	(-.0709 $\pm$.0165)	0.859

Table A-18

Reduction statistics of enteric bacteria species with Phormidium faveolarum.
Series BG-II. Bacteria and algae inoculated within
twenty-four hours of one another.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	35.483	1.4550	(5.5216 $\pm$ 1.2415)	(-.0880 $\pm$.0275)	0.816
<u>Enterobacter aerogenes</u>					
12	9.3918	1.8409	(4.7479 $\pm$ 1.4742)	(-.0594 $\pm$.0367)	0.573
<u>Escherichia coli</u>					
12	10.2230	3.2589	(5.1780 $\pm$ 1.7090)	(-.0552 $\pm$.0313)	0.505
<u>Proteus vulgaris</u>					
12	9.5460	1.2614	(5.7131 $\pm$ 2.0473)	(-.1567 $\pm$.1194)	0.761
<u>Pseudomonas aeruginosa</u>					
12	54.309	0.5361	(6.9504 $\pm$ 1.3347)	(-.2437 $\pm$.0778)	0.948
<u>Serratia marcescens</u>					
12	10.628	2.1393	(4.4701 $\pm$ 1.3846)	(-.0456 $\pm$.0254)	0.515

Table A-19

Reduction statistics of bacterial contaminants of Anabaena cylindrica during series BG-II with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
13	44.545	0.0424	(8.9466 $\pm$.2816)	(-.0187 $\pm$.0054)	0.881
<u>Enterobacter aerogenes</u>					
12	5.8129	2.3427	(8.2424 $\pm$.6616)	(-.0159 $\pm$.0128)	0.492
<u>Escherichia coli</u>					
12	2.0875	0.3648	(8.6235 $\pm$ 1.0190)	(-.0175 $\pm$.0258)	0.343
<u>Proteus vulgaris</u>					
12	0.7149	0.6621	(8.1277 $\pm$ 1.1123)	(-.0094 $\pm$.0215)	0.106
<u>Pseudomonas aeruginosa</u>					
13	5.9898	0.2366	(8.6531 $\pm$.7359)	(-.0198 $\pm$.0163)	0.545
<u>Serratia marcescens</u>					
13	10.141	0.1349	(8.8000 $\pm$.6195)	(-.0234 $\pm$.0157)	0.717

Table A-20

Reduction statistics of bacterial contaminants of Anacystis nidulans during series BG-II with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
13	32.316	0.0324	(8.5258 $\pm$.2666)	(-.0197 $\pm$.0074)	0.890
<u>Enterobacter aerogenes</u>					
12	14.086	0.1689	(8.8843 $\pm$.5258)	(-.0213 $\pm$.0114)	0.738
<u>Escherichia coli</u>					
12	3.7262	0.3657	(8.3519 $\pm$.7735)	(-.0161 $\pm$.0168)	0.427
<u>Proteus vulgaris</u>					
12	16.150	0.2533	(8.5266 $\pm$.6437)	(-.0279 $\pm$.0140)	0.763
<u>Pseudomonas aeruginosa</u>					
12	0.3013	0.4104	(7.6799 $\pm$.9494)	(-.0068 $\pm$.0263)	0.070
<u>Serratia marcescens</u>					
12	26.612	0.1054	(8.4857 $\pm$.4812)	(-.0323 $\pm$.0133)	0.869

Table A-21

Reduction statistics of bacterial contaminants of Gloeocapsa alpicola
during Series BG-II with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
13	3.2359	0.2076	(7.9638 $\pm$.6747)	(-.0110 $\pm$.0130)	0.447
<u>Enterobacter aerogenes</u>					
12	13.108	0.1672	(8.1383 $\pm$.6055)	(-.0198 $\pm$.0117)	0.766
<u>Escherichia coli</u>					
12	5.7870	0.3437	(8.8736 $\pm$ 1.0537)	(-.0271 $\pm$.0265)	0.658
<u>Proteus vulgaris</u>					
12	8.1439	0.1337	(8.5076 $\pm$.5415)	(-.0139 $\pm$.0104)	0.671
<u>Pseudomonas aeruginosa</u>					
12	6.4973	0.0826	(7.9595 $\pm$.5167)	(-.0141 $\pm$.0130)	0.684
<u>Serratia marcescens</u>					
12	16.613	0.1527	(8.2359 $\pm$.5786)	(-.0213 $\pm$.0111)	0.806

Table A-22

Reduction statistics of bacterial contaminants of Oscillatoria chalybia
during series BG-II with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	24.990	0.0192	(7.6573 $\pm$.2627)	(-.0110 $\pm$.0052)	0.893
<u>Enterobacter aerogenes</u>					
12	24.106	0.0310	(7.7886 $\pm$.3343)	(-.0138 $\pm$.0066)	0.889
<u>Escherichia coli</u>					
12	12.224	0.0996	(8.3854 $\pm$.5177)	(-.0143 $\pm$.0087)	0.753
<u>Proteus vulgaris</u>					
12	0.2826	0.1938	(7.4938 $\pm$.8353)	(-.0037 $\pm$.0165)	0.086
<u>Pseudomonas aeruginosa</u>					
12	0.0174	0.0899	(7.1715 $\pm$.5690)	(.0006 $\pm$.0112)	0.006
<u>Serratia marcescens</u>					
12	0.7189	0.1208	(7.3817 $\pm$.6596)	(-.0047 $\pm$.0130)	0.193

Table A-23

Reduction statistics of bacterial contaminants of Oscillatoria formosa
during series BG-II with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	0.0758	0.2549	(7.7277 $\pm$.7207)	(-.0018 $\pm$.0139)	0.019
<u>Enterobacter aerogenes</u>					
12	0.4654	0.3258	(7.7450 $\pm$.8148)	(-.0051 $\pm$.0158)	0.104
<u>Escherichia coli</u>					
12	3.7691	0.2270	(8.0401 $\pm$.6801)	(-.0120 $\pm$.0132)	0.485
<u>Proteus vulgaris</u>					
12	36.3346	0.0251	(8.0503 $\pm$.2259)	(-.0124 $\pm$.0044)	0.901
<u>Pseudomonas aeruginosa</u>					
12	1.5084	0.1332	(7.7167 $\pm$.5209)	(-.0058 $\pm$.0101)	0.274
<u>Serratia marcescens</u>					
12	1.1490	1.4257	(7.8396 $\pm$.9224)	(-.0129 $\pm$.0352)	0.365

Table A-24

Reduction statistics of bacterial contaminants of Phormidium faveolarum
during series BG-II with enteric bacteria.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	3.8100	0.1202	(7.7007 $\pm$ 2.0520)	(-.0195 $\pm$.0630)	0.792
<u>Enterobacter aerogenes</u>					
12	7.2137	0.1341	(7.8364 $\pm$.9043)	(-.0174 $\pm$.0189)	0.783
<u>Escherichia coli</u>					
12	10.6154	0.2067	(8.1078 $\pm$ 1.1228)	(-.0262 $\pm$.0235)	0.841
<u>Proteus vulgaris</u>					
12	2.8200	0.2284	(7.7159 $\pm$ 1.1805)	(-.0142 $\pm$.0247)	0.585
<u>Pseudomonas aeruginosa</u>					
12	2.6126	0.0269	(6.2282 $\pm$.4053)	(.0047 $\pm$.0085)	0.566
<u>Serratia marcescens</u>					
12	2.8029	1.2669	(7.4335 $\pm$ 6.6603)	(-.0542 $\pm$.2044)	0.737

Table A-25

Growth statistics of bacteria found in axenic algae cultures.
Series BG-III. Controls.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Anabaena cylindrica</u>					
11	3.6350	5.0979	(3.7588 $\pm$ 3.2707)	(.0557 $\pm$.0622)	0.476
<u>Anacystis nidulans</u>					
10	2.4846	5.8369	(3.5555 $\pm$ 3.5177)	(.0495 $\pm$.0669)	0.383
<u>Gloeocapsa alpicola</u>					
12	14.403	1.4564	(1.8642 $\pm$ 1.7482)	(.0592 $\pm$.0333)	0.783
<u>Oscillatoria chalybia</u>					
12	6.0545	2.3982	(3.9318 $\pm$ 2.2433)	(.0493 $\pm$.0427)	0.602
<u>Oscillatoria formosa</u>					
12	3.0423	3.4652	(4.4801 $\pm$ 2.6966)	(.0420 $\pm$.0513)	0.432
<u>Phormidium faveolarum</u>					
12	4.5869	2.7219	(4.1262 $\pm$ 2.3899)	(.0457 $\pm$.0455)	0.534

Table A-26

Growth statistics of axenic culture of Anabaena cylindrica with enteric
bacteria during series BG-I run. Series BG-IV.
Results based on mg/l dry weight.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
11	6.2784	0.0564	(1.4545 $\pm$.5655)	(.0117 $\pm$.0099)	0.611
<u>Enterobacter aerogenes</u>					
11	8.6185	0.0342	(1.7229 $\pm$.4403)	(.0107 $\pm$.0079)	0.683
<u>Escherichia coli</u>					
11	0.4352	0.1098	(1.8928 $\pm$.7893)	(.0043 $\pm$.0139)	0.098
<u>Proteus vulgaris</u>					
11	2.9086	0.1148	(1.4919 $\pm$.8073)	(.0114 $\pm$.0143)	0.421
<u>Pseudomonas aeruginosa</u>					
11	10.575	0.0580	(1.2489 $\pm$.5738)	(.0155 $\pm$.0101)	0.725
<u>Serratia marcescens</u>					
11	12.066	0.0493	(1.2862 $\pm$.5288)	(.0152 $\pm$.0093)	0.751

Table A-27

Growth statistics of axenic culture of Anacystis nidulans with enteric bacteria during series BG-I run. Series BG-IV.
Results based on mg/l dry weight.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
11	2.7980	0.1230	(1.4449 [±] .8355)	(.0116 [±] .0148)	0.411
<u>Enterobacter aerogenes</u>					
11	5.5746	0.0575	(1.1917 [±] .5714)	(.0112 [±] .0101)	0.582
<u>Escherichia coli</u>					
11	67.451	0.0065	(1.602 [±] .1919)	(.0131 [±] .0034)	0.944
<u>Proteus vulgaris</u>					
11	2.7309	0.0389	(1.5815 [±] .4699)	(.0064 [±] .0083)	0.406
<u>Pseudomonas aeruginosa</u>					
11	1.5814	0.1693	(1.3273 [±] .9802)	(.0102 [±] .0173)	0.283
<u>Serratia marcescens</u>					
11	6.3484	0.0513	(1.3299 [±] .5398)	(.0113 [±] .0095)	0.613

Table A-28

Growth statistics of axenic culture of Gloeocapsa alpicola with enteric bacteria during series BG-I run. Series BG-IV.
Results based on mg/l dry weight.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
11	1.9229	0.0928	(1.6702 [±] .7257)	(.0083 [±] .0128)	0.324
<u>Enterobacter aerogenes</u>					
11	4.2808	0.0297	(1.9153 [±] .4106)	(.0070 [±] .0072)	0.517
<u>Escherichia coli</u>					
11	5.7088	0.0326	(1.7957 [±] .4299)	(.0085 [±] .0076)	0.588
<u>Proteus vulgaris</u>					
11	0.6004	0.0673	(2.1234 [±] .6180)	(.0039 [±] .0109)	0.130
<u>Pseudomonas aeruginosa</u>					
11	4.3449	0.0140	(2.0407 [±] .2821)	(.0049 [±] .0050)	0.521
<u>Serratia marcescens</u>					
11	17.924	0.0203	(1.5473 [±] .3396)	(.0119 [±] .0060)	0.817

Table A-29

Growth statistics of axenic culture of Oscillatoria chalybia with enteric bacteria during series BG-I run. Series BG-IV.
Results based on mg/l dry weight.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
11	8.9103	0.0203	(1.5632 $\pm$.3391)	(.0084 $\pm$.0059)	0.690
<u>Enterobacter aerogenes</u>					
11	8.5231	0.0134	(1.6601 $\pm$.2759)	(.0067 $\pm$.0048)	0.681
<u>Escherichia coli</u>					
11	0.7271	0.0860	(1.9015 $\pm$.6988)	(.0049 $\pm$.0123)	0.154
<u>Proteus vulgaris</u>					
11	26.7943	0.0343	(1.7519 $\pm$.4414)	(.0189 $\pm$.0078)	0.870
<u>Pseudomonas aeruginosa</u>					
11	10.575	0.0580	(1.2489 $\pm$.5738)	(.0155 $\pm$.0101)	0.725
<u>Serratia marcescens</u>					
11	12.066	0.0493	(1.2862 $\pm$.5288)	(.0152 $\pm$.0093)	0.751

Table A-30

Growth statistics of axenic culture of Oscillatoria formosa with enteric bacteria during series BG-I run. Series BG-IV.
Results based on mg/l dry weight.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	12.215	0.1702	(.6819 $\pm$.9829)	(.0285 $\pm$.0174)	0.753
<u>Enterobacter aerogenes</u>					
11	22.734	0.0742	(1.0015 $\pm$.6489)	(.0256 $\pm$.0115)	0.850
<u>Escherichia coli</u>					
13	9.3189	0.1202	(1.1998 $\pm$.8261)	(.0209 $\pm$.0146)	0.699
<u>Proteus vulgaris</u>					
12	2.9976	0.2196	(1.3486 $\pm$ 1.1164)	(.0160 $\pm$.0197)	0.428
<u>Pseudomonas aeruginosa</u>					
11	1.4971	0.1744	(1.5118 $\pm$.9948)	(.0101 $\pm$.0176)	0.272
<u>Serratia marcescens</u>					
11	3.3157	0.1967	(1.3871 $\pm$ 1.0566)	(.0159 $\pm$.0187)	0.453

Table A-31

Growth statistics of axenic culture of Phormidium faveolarum with enteric bacteria during series BG-I run, Series BG-IV.

Results based on mg/l dry weight.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
11	0.0620	0.0763	(2.1178 [±] .6583)	(.0013 [±] .0116)	0.015
<u>Enterobacter aerogenes</u>					
12	0.0144	0.0504	(2.0452 [±] .5349)	(.0005 [±] .0094)	0.004
<u>Escherichia coli</u>					
12	0.4124	0.0444	(2.1646 [±] .5023)	(-.0027 [±] .0088)	0.093
<u>Proteus vulgaris</u>					
12	0.4748	0.1242	(1.6443 [±] .8396)	(.0048 [±] .0148)	0.106
<u>Pseudomonas aeruginosa</u>					
12	0.1167	0.0785	(2.0089 [±] .6676)	(-.0019 [±] .0118)	0.028
<u>Serratia marcescens</u>					
12	1.1185	0.0804	(2.3023 [±] .6755)	(-.0059 [±] .0119)	0.218

Table A-32

Reduction statistics of enteric bacteria species with algal contaminant Brevibacterium, Series BG-V.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	11.847	1.3542	(6.7687 [±] 1.5672)	(-.0513 [±] .0300)	0.703
<u>Enterobacter aerogenes</u>					
12	61.275	2.4412	(8.3011 [±] .6642)	(-.0494 [±] .0127)	0.924
<u>Escherichia coli</u>					
12	15.235	0.2289	(8.4366 [±] .6432)	(-.0755 [±] .0123)	0.968
<u>Proteus vulgaris</u>					
12	115.08	0.4806	(8.4680 [±] .9319)	(-.0951 [±] .0178)	0.958
<u>Pseudomonas aeruginosa</u>					
12	28.100	1.2490	(7.6973 [±] 1.7243)	(-.1011 [±] .0407)	0.875
<u>Serratia marcescens</u>					
12	55.697	0.427	(8.6455 [±] .8787)	(-.0624 [±] .0168)	0.918

Table A-33

Reduction statistics of enteric bacteria species with algal contaminant, Flaveobacterium, Series BG-V.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	19.699	1.0269	(8.1993 $\pm$ 2.4757)	(-.1437 $\pm$.0945)	0.908
<u>Enterobacter aerogenes</u>					
12	188.33	0.0543	(8.0086 $\pm$ 1.3435)	(-.1616 $\pm$.0743)	0.995
<u>Escherichia coli</u>					
12	21.881	1.4051	(8.1903 $\pm$ 1.8289)	(-.0947 $\pm$.0431)	0.845
<u>Proteus vulgaris</u>					
12	136.43	0.3321	(10.0665 $\pm$ 1.0505)	(-.1520 $\pm$.0306)	0.978
<u>Pseudomonas aeruginosa</u>					
12	22.289	0.9558	(7.6614 $\pm$ 1.7822)	(-.1042 $\pm$.0519)	0.881
<u>Serratia marcescens</u>					
12	16.282	1.6677	(6.5629 $\pm$ 1.7360)	(-.0666 $\pm$.0333)	0.765

Table A-34

Reduction statistics of single species of enteric bacteria in presence of mixed cultures of six species of blue-green algae. Series BG-VIII.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
13	15.939	1.4918	(7.7778 $\pm$ 7.0397)	(-.2463 $\pm$.3895)	0.941
<u>Enterobacter aerogenes</u>					
12	6.2346	3.5258	(8.1472 $\pm$ 10.8224)	(-.2368 $\pm$.5988)	0.862
<u>Escherichia coli</u>					
13	0.3556	2.9060	(7.0455 $\pm$ 7.1646)	(-.1666 $\pm$.1590)	0.824
<u>Proteus vulgaris</u>					
13	5.4117	4.1432	(8.1208 $\pm$ 11.7319)	(-.2392 $\pm$.6491)	0.844
<u>Pseudomonas aeruginosa</u>					
12	10.783	2.7206	(7.0364 $\pm$ 4.0296)	(-.1730 $\pm$.1538)	0.843
<u>Serratia marcescens</u>					
12	4.2473	5.0527	(6.4926 $\pm$ 5.4915)	(-.1479 $\pm$.2096)	0.679

Table A-35

Reduction statistics of mixed enteric bacteria in presence of mixed cultures of six species of blue-green algae. Series BG-IX.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
11	14.056	1.8856	(6.7616 $\pm$ 7.9146)	(-.2600 $\pm$.4379)	0.933
<u>Enterobacter aerogenes</u>					
11	5.9160	4.9779	(6.8051 $\pm$ 12.8595)	(-.2741 $\pm$.7115)	0.855
<u>Escherichia coli</u>					
11	0.0786	19.409	(4.1152 $\pm$ 19.6689)	(-.1081 $\pm$ 2.4333)	0.073
<u>Proteus vulgaris</u>					
11	4.3410	5.6157	(6.2648 $\pm$ 12.6453)	(-.1632 $\pm$.4947)	0.813
<u>Pseudomonas aeruginosa</u>					
11	13.145	1.7591	(6.9496 $\pm$ 3.2402)	(-.1536 $\pm$.1237)	0.868
<u>Serratia marcescens</u>					
11	36.931	0.5183	(7.0223 $\pm$ 1.7588)	(-.1397 $\pm$.0671)	0.948
<u>Total* of all 6 enterics</u>					
11	20.528	1.1271	(7.5912 $\pm$ 2.5936)	(-.1536 $\pm$.0990)	0.911

* Data for the total number of enteric bacteria, not sum of individual statistical results for each species.

Table A-36

Reduction statistics of enteric bacteria species with Ankistrodesmus braunii.
Series G-I. Bacteria added to algae when in mid-log phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
13	59.850	0.45717	(7.0994 $\pm$.9669)	(-.0701 $\pm$.0193)	0.937
<u>Enterobacter aerogenes</u>					
14	89.272	0.36307	(8.2215 $\pm$.8617)	(-.0764 $\pm$.0172)	0.957
<u>Escherichia coli</u>					
14	7.1998	1.0295	(6.7241 $\pm$ 1.4509)	(-.0365 $\pm$.0290)	0.643
<u>Proteus vulgaris</u>					
11	38.053	0.35906	(6.9891 $\pm$ 1.0566)	(-.0756 $\pm$.0288)	0.927
<u>Pseudomonas aeruginosa</u>					
12	42.717	0.29243	(7.9607 $\pm$ 1.3211)	(-.1129 $\pm$.0504)	0.955
<u>Serratia marcescens</u>					
12	11.093	0.82891	(9.1086 $\pm$ 1.6055)	(-.0620 $\pm$.0438)	0.787

Table A-37

Reduction statistics of enteric bacteria species with Chlorella pyrenoidosa.
Series G-I. Bacteria added to algae when in mid-log phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
13	447.65	.05507	(8.1764 $\pm$.5733)	(-.1586 $\pm$.0219)	0.995
<u>Enterobacter aerogenes</u>					
14	9.3163	2.6364	(7.7223 $\pm$ 2.8633)	(-.1013 $\pm$.0781)	0.756
<u>Escherichia coli</u>					
14	19.113	1.1338	(6.6677 $\pm$ 1.5227)	(-.0624 $\pm$.0305)	0.827
<u>Proteus vulgaris</u>					
11	23.078	1.3761	(8.2918 $\pm$ 2.8659)	(-.1800 $\pm$.1094)	0.920
<u>Pseudomonas aeruginosa</u>					
12	9.1331	2.5412	(8.0134 $\pm$ 2.8111)	(-.0985 $\pm$.0767)	0.753
<u>Serratia marcescens</u>					
12	17.501	0.0995	(7.0495 $\pm$ 1.7629)	(-.0855 $\pm$.0481)	0.854

Table A-38

Reduction statistics of enteric bacteria species with Chlorella vulgaris.
Series G-I. Bacteria added to algae when in mid-log phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	8.5477	1.8059	(7.1179 $\pm$ 3.2831)	(-.1255 $\pm$.1253)	0.810
<u>Enterobacter aerogenes</u>					
12	6.7731	3.1823	(7.1567 $\pm$ 3.1458)	(-.0949 $\pm$ 0.0858)	0.693
<u>Escherichia coli</u>					
12	4.2474	2.8177	(6.5618 $\pm$ 2.4005)	(-.0464 $\pm$ 0.0480)	0.515
<u>Proteus vulgaris</u>					
12	6.2347	2.0976	(8.1411 $\pm$ 8.3476)	(-.1826 $\pm$.4619)	0.862
<u>Pseudomonas aeruginosa</u>					
12	19.549	1.4598	(8.1344 $\pm$ 2.1307)	(-.1092 $\pm$.0581)	0.867
<u>Serratia marcescens</u>					
12	12.080	1.8887	(7.9809 $\pm$ 3.0490)	(-.0651 $\pm$.0547)	0.858

Table A-39

Reduction statistics of enteric bacteria species with Scenedesmus obliquus.
Series G-I. Bacteria added to algae when in mid-log phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	7.1587	1.6250	(6.1286 $\pm$ 1.8230)	(-.0458 $\pm$.0365)	0.642
<u>Enterobacter aerogenes</u>					
12	26.533	0.6903	(6.9105 $\pm$ 1.1881)	(-.0574 $\pm$.0238)	0.869
<u>Escherichia coli</u>					
12	40.527	0.2004	(7.4914 $\pm$ 0.7894)	(-.0583 $\pm$.0215)	0.931
<u>Proteus vulgaris</u>					
12	17.165	1.1059	(6.9057 $\pm$ 1.8545)	(-.0891 $\pm$.0506)	0.851
<u>Pseudomonas aeruginosa</u>					
12	26.296	0.5495	(7.9135 $\pm$ 1.3072)	(-.0777 $\pm$.0357)	0.898
<u>Serratia marcescens</u>					
12	41.964	0.5409	(8.8431 $\pm$ 1.2969)	(-.0974 $\pm$.0354)	0.933

Table A-40

Reduction statistics of enteric bacteria species with Ankistrodesmus braunii.
Series G-II. Bacteria and algae inoculated within twenty-four hours of one another

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	154.98	0.19994	(8.7434 $\pm$ 2.4481)	(-.0857 $\pm$.0435)	0.994
<u>Enterobacter aerogenes</u>					
12	17.603	1.5360	(8.5471 $\pm$ 6.7856)	(-.0801 $\pm$.1205)	0.946
<u>Escherichia coli</u>					
12	4.5853	2.7007	(7.8609 $\pm$ 8.9976)	(-.0542 $\pm$.1598)	0.821
<u>Proteus vulgaris</u>					
12	1.8897	12.398	(7.2077 $\pm$ 19.278)	(-.0745 $\pm$.3424)	0.654
<u>Pseudomonas aeruginosa</u>					
12	1765.9	0.01860	(8.9704 $\pm$.8609)	(-.1977 $\pm$.0297)	0.999
<u>Serratia marcescens</u>					
12	1891.1	0.01366	(9.7349 $\pm$.7378)	(-.1753 $\pm$.0254)	0.999

Table A-41

Reduction statistics of enteric bacteria species with Chlorella pyrenoidosa.
Series G-II. Bacteria and algae inoculated within twenty-four hours of one another.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	24.159	0.9386	(7.9536 $\pm$ 5.3042)	(-.0743 $\pm$.0942)	0.960
<u>Enterobacter aerogenes</u>					
12	2899.2	0.0046	(9.2054 $\pm$.4299)	(-.1265 $\pm$.0148)	0.999
<u>Escherichia coli</u>					
12	12.115	2.0249	(7.7306 $\pm$ 7.7908)	(-.0763 $\pm$.1384)	0.924
<u>Proteus vulgaris</u>					
12	69.343	0.1855	(7.0642 $\pm$ 2.3582)	(-.0552 $\pm$.0419)	0.986
<u>Pseudomonas aeruginosa</u>					
12	10.876	1.2791	(8.0599 $\pm$ 6.1921)	(-.0574 $\pm$.1100)	0.916
<u>Serratia marcescens</u>					
12	19.603	0.6550	(8.2736 $\pm$ 4.4309)	(-.0552 $\pm$.0787)	0.951

Table A-42

Reduction statistics of enteric bacteria species with Chlorella vulgaris. Series G-II. Bacteria and algae inoculated within twenty-four hours of one another.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	2125.2	0.00398	(5.9987 $\pm$.3983)	(-.1003 $\pm$.0137)	0.999
<u>Enterobacter aerogenes</u>					
12	2156.9	0.00505	(7.5548 $\pm$.4487)	(-.1138 $\pm$.0155)	0.999
<u>Escherichia coli</u>					
12	4.0005	1.7486	(5.6424 $\pm$ 7.2399)	(-.0407 $\pm$.1286)	0.800
<u>Proteus vulgaris</u>					
12	2362.9	0.0065	(8.1123 $\pm$.5091)	(-.1352 $\pm$.0176)	0.999
<u>Pseudomonas aeruginosa</u>					
12	4933.7	0.0062	(7.4898 $\pm$.4954)	(-.1901 $\pm$.0171)	0.999
<u>Serratia marcescens</u>					
12	1781.4	0.0046	(6.6976 $\pm$.4292)	(-.0989 $\pm$.0148)	0.999

Table A-43

Reduction statistics of enteric bacteria species with Scenedesmus obliquus. Series G-II. Bacteria and algae inoculated within twenty-four hours of one another.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	847.23	0.02134	(7.4529 $\pm$.7997)	(-.0655 $\pm$.0142)	0.998
<u>Enterobacter aerogenes</u>					
12	5911.5	0.00448	(8.3051 $\pm$.3663)	(-.0792 $\pm$.0065)	0.999
<u>Escherichia coli</u>					
12	29.286	0.42066	(6.7184 $\pm$ 3.5509)	(-.0541 $\pm$.0631)	0.967
<u>Proteus vulgaris</u>					
12	1821.5	0.00183	(6.4763 $\pm$.2699)	(-.0629 $\pm$.0093)	0.999
<u>Pseudomonas aeruginosa</u>					
12	2.1169	4.3286	(6.6961 $\pm$ 11.3908)	(-.0466 $\pm$.2023)	0.679
<u>Serratia marcescens</u>					
12	7.6209	1.3397	(7.5169 $\pm$ 6.3371)	(-.0492 $\pm$.1126)	0.884

Table A-44

Reduction statistics of single species of enteric bacteria in presence of mixed cultures of four species of green algae. Series G-VIII.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	47.994	0.5460	(7.5188 $\pm$ 1.8052)	(-.1635 $\pm$.0689)	0.959
<u>Enterobacter aerogenes</u>					
12	145.79	0.1437	(6.6479 $\pm$.9259)	(-.1462 $\pm$.0353)	0.986
<u>Escherichia coli</u>					
12	23.382	0.6871	(6.8582 $\pm$ 2.0250)	(-.1280 $\pm$.0773)	0.921
<u>Proteus vulgaris</u>					
12	7.9498	1.8035	(7.3760 $\pm$ 7.7403)	(-.1912 $\pm$.4282)	0.888
<u>Pseudomonas aeruginosa</u>					
12	71.674	0.4158	(8.1735 $\pm$ 1.5754)	(-.1744 $\pm$.0601)	0.973
<u>Serratia marcescens</u>					
12	59.165	0.3693	(7.2299 $\pm$ 1.4847)	(-.1493 $\pm$.0567)	0.967

Table A-45

Reduction statistics of mixed enteric bacteria in presence of mixed cultures of four species of green algae. Series G-IX.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
11	4.6588	1.1638	(6.6735 $\pm$ 6.2179)	(-.1176 $\pm$.3440)	0.823
<u>Enterobacter aerogenes</u>					
13	2.2508	0.7552	(6.9674 $\pm$ 5.0089)	(-.2082 $\pm$.2771)	0.957
<u>Escherichia coli</u>					
13	17.089	1.1520	(7.3603 $\pm$ 2.6222)	(-.1417 $\pm$.1001)	0.895
<u>Proteus vulgaris</u>					
12	3.4883	3.4136	(6.8254 $\pm$ 10.650)	(-.1743 $\pm$.5893)	0.777
<u>Pseudomonas aeruginosa</u>					
12	11.588	1.8844	(7.4373 $\pm$ 3.3536)	(-.1493 $\pm$.1280)	0.853
<u>Serratia marcescens</u>					
12	27.099	0.9017	(7.6250 $\pm$ 2.3198)	(-.1579 $\pm$.0885)	0.931
<u>Total enteric count (all six above)</u>					
12	21.552	1.0055	(8.1321 $\pm$ 2.4497)	(-.1487 $\pm$.0935)	0.915

Table A-46

Reduction statistics of enteric bacteria species in algal growth medium.
Series VI.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	2.2010	2.7828	(6.9431 [±] 1.2267)	(-.0228 [±] .0279)	0.180
<u>Enterobacter aerogenes</u>					
12	0.3045	3.6089	(6.0233 [±] 1.3969)	(-.0097 [±] .0317)	0.029
<u>Escherichia coli</u>					
12	2.1764	2.4862	(6.3741 [±] 1.1595)	(-.0214 [±] .0263)	0.179
<u>Proteus vulgaris</u>					
12	0.6976	3.7817	(6.1353 [±] 1.4299)	(-.0149 [±] .0325)	0.065
<u>Pseudomonas aeruginosa</u>					
12	1.1722	1.7682	(6.9922 [±] .9778)	(-.0133 [±] .0222)	0.105
<u>Serratia marcescens</u>					
12	0.3976	2.880	(7.1737 [±] 1.2479)	(-.0098 [±] .0283)	0.038

Table A-47

Reduction statistics of enteric bacteria species in filtrate from Anabaena cylindrica at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
11	6.4853	0.2025	(7.7104 ⁺ 2.4823)	(-.0230 ⁺ .0570)	0.866
<u>Enterobacter aerogenes</u>					
12	5.7437	0.4313	(7.4657 ⁺ 3.6224)	(-.0316 ⁺ .0832)	0.852
<u>Escherichia coli</u>					
12	3.2604	0.2060	(8.0062 ⁺ 2.5035)	(-.0164 ⁺ .0575)	0.765
<u>Proteus vulgaris</u>					
12	2.5121	0.6346	(7.4696 ⁺ 4.3939)	(-.0253 ⁺ .1009)	0.715
<u>Pseudomonas aeruginosa</u>					
12	3.7237	0.1872	(7.7903 ⁺ 2.3862)	(-.0167 ⁺ .0548)	0.788
<u>Serratia marcescens</u>					
12	2.2672	0.1520	(7.8025 ⁺ 2.1506)	(-.0118 ⁺ .0494)	0.694

Table A-48

Reduction statistics of enteric bacteria species in filtrate from Anacystis nidulans at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	11.972	0.2918	(7.8427 ⁺ 2.9796)	(-.0375 ⁺ .0684)	0.923
<u>Enterobacter aerogenes</u>					
12	53.426	0.1023	(7.8034 ⁺ 1.7639)	(-.0469 ⁺ .0405)	0.982
<u>Escherichia coli</u>					
12	4.1309	0.2715	(7.5976 ⁺ 2.8743)	(-.0212 ⁺ .0660)	0.805
<u>Proteus vulgaris</u>					
12	9.7873	0.6997	(7.3661 ⁺ 4.6137)	(-.0525 ⁺ .1060)	0.907
<u>Pseudomonas aeruginosa</u>					
12	5.2270	0.4748	(8.0166 ⁺ 3.8006)	(-.0316 ⁺ .0873)	0.839
<u>Serratia marcescens</u>					
12	3.0764	0.7320	(7.4349 ⁺ 4.7190)	(-.0301 ⁺ .1084)	0.754

Table A-49

Reduction statistics of enteric bacteria species in filtrate from Gloeocapsa alpicola at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	3.2476	0.1193	(8.5132 ⁺ 1.9048)	(-.0395 ⁺ .0437)	0.970
<u>Enterobacter aerogenes</u>					
12	1016.5	0.0087	(9.2218 ⁺ .5138)	(-.0596 ⁺ .0118)	0.999
<u>Escherichia coli</u>					
12	2537.2	0.0042	(8.6674 ⁺ .3579)	(-.0656 ⁺ .0082)	0.999
<u>Proteus vulgaris</u>					
12	93.455	0.0594	(9.1244 ⁺ 1.3448)	(-.0473 ⁺ .0309)	0.989
<u>Pseudomonas aeruginosa</u>					
14	7.3096	0.1320	(8.6017 ⁺ 2.0040)	(-.0197 ⁺ .0460)	0.879
<u>Serratia marcescens</u>					
12	0.3661	2.9428	(7.7528 ⁺ 9.4620)	(-.0208 ⁺ .2174)	0.268

Table A-50

Reduction statistics of enteric bacteria species in filtrate from Nostoc muscorum at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
14	6.2929	2.9351	(7.5992 ⁺ 9.4495)	(-.0862 ⁺ .2171)	0.863
<u>Enterobacter aerogenes</u>					
11	29.8502	0.8679	(8.2287 ⁺ 5.1385)	(-.1021 ⁺ .1180)	0.967
<u>Escherichia coli</u>					
12	22.339	0.8631	(8.0406 ⁺ 5.1242)	(-.0881 ⁺ .1177)	0.957
<u>Proteus vulgaris</u>					
12	6768.7	0.0038	(8.2417 ⁺ .3411)	(-.1021 ⁺ .0078)	0.999
<u>Pseudomonas aeruginosa</u>					
12	8.9025	1.1393	(7.5259 ⁺ 5.8874)	(-.0639 ⁺ .1352)	0.899
<u>Serratia marcescens</u>					
12	15.896	0.5653	(7.6208 ⁺ 4.1472)	(-.602 ⁺ .0953)	0.941

Table A-51

Reduction statistics of enteric bacteria species in filtrate from Oscillatoria chalybia at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	18.221	1.2523	(8.0115 ⁺ 6.4142)	(-.0996 ⁺ .1473)	0.948
<u>Enterobacter aerogenes</u>					
12	19.231	1.1985	(7.4310 ⁺ 6.0384)	(-.0963 ⁺ .1387)	0.951
<u>Escherichia coli</u>					
12	8.7375	2.9108	(7.7619 ⁺ 9.4103)	(-.1012 ⁺ .2162)	0.897
<u>Proteus vulgaris</u>					
12	13.628	1.6409	(7.2278 ⁺ 7.0653)	(-.0949 ⁺ .1623)	0.932
<u>Pseudomonas aeruginosa</u>					
12	54.986	0.3240	(7.3250 ⁺ 3.1396)	(0.0847 ⁺ .0721)	0.982
<u>Serratia marcescens</u>					
12	5.2723	3.0540	(7.7516 ⁺ 9.6390)	(-.0805 ⁺ .2214)	0.840

Table A-52

Reduction statistics of enteric bacteria species in filtrate from Oscillatoria formosa at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	2.3677	6.0714	(7.1292 ⁺ 13.5907)	(-.0761 ⁺ .3122)	0.703
<u>Enterobacter aerogenes</u>					
12	7.9584	1.6716	(8.1111 ⁺ 7.1312)	(-.0732 ⁺ .1638)	0.888
<u>Escherichia coli</u>					
12	0.7880	0.5797	(3.1487 ⁺ 4.1997)	(.0136 ⁺ .0965)	0.441
<u>Proteus vulgaris</u>					
12	5.0901	2.2407	(7.5433 ⁺ 8.2564)	(-.0678 ⁺ .1897)	0.836
<u>Pseudomonas aeruginosa</u>					
12	24.278	0.3300	(8.4717 ⁺ 3.1687)	(-.0568 ⁺ .0728)	0.960
<u>Serratia marcescens</u>					
12	4.2481	2.6330	(8.1498 ⁺ 8.9501)	(-.0671 ⁺ .2056)	0.809

Table A-53

Reduction statistics of enteric bacteria species in filtrate from Phormidium faveolanum at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	6.9894	1.7256	(7.4942 ⁺ 7.2456)	(-.0697 ⁺ .1664)	0.875
<u>Enterobacter aerogenes</u>					
14	14.285	1.2290	(8.1289 ⁺ 6.1147)	(-.0841 ⁺ .1405)	0.934
<u>Escherichia coli</u>					
14	2.4922	4.1571	(7.7636 ⁺ 11.2459)	(-.0646 ⁺ .2584)	0.714
<u>Proteus vulgaris</u>					
11	28.032	0.3666	(7.7698 ⁺ 2.2297)	(-.0643 ⁺ .0767)	0.965
<u>Pseudomonas aeruginosa</u>					
13	8.2261	1.4944	(7.6431 ⁺ 6.7427)	(-.0704 ⁺ .1549)	0.892
<u>Serratia marcescens</u>					
13	14.772	1.1057	(8.6154 ⁺ 5.7998)	(-.0811 ⁺ .1332)	0.936

Table A-54

Reduction statistics of enteric bacteria species in filtrate from Ankistrodesmus braunii at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	3.0478	4.8141	(7.7835 ⁺ 12.1020)	(-.0769 ⁺ .2780)	0.753
<u>Enterobacter aerogenes</u>					
12	12.906	1.7917	(7.9340 ⁺ 7.3829)	(-.0965 ⁺ .1696)	0.928
<u>Escherichia coli</u>					
14	1342.78	0.0050	(7.3121 ⁺ .3902)	(-.0520 ⁺ .0090)	0.999
<u>Proteus vulgaris</u>					
14	93.518	0.2169	(7.3531 ⁺ 2.5691)	(-.0904 ⁺ .0590)	0.989
<u>Pseudomonas aeruginosa</u>					
14	55.977	0.3512	(7.9651 ⁺ 3.2685)	(-.0890 ⁺ .0751)	0.982
<u>Serratia marcescens</u>					
12	8.6920	0.8912	(7.2218 ⁺ 5.2069)	(-.0558 ⁺ .1196)	0.897

Table A-55

Reduction statistics of enteric bacteria species in filtrate from Chlorella pyrenoidosa at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
12	5.4223	3.9217	(7.4986 $\pm$ 10.9228)	(-.0925 $\pm$.2509)	0.844
<u>Enterobacter aerogenes</u>					
12	6.9282	2.5946	(7.5341 $\pm$ 8.8844)	(-.0851 $\pm$.2041)	0.874
<u>Escherichia coli</u>					
12	1.8148	6.8664	(7.2231 $\pm$ 14.4531)	(-.0708 $\pm$.3320)	0.645
<u>Proteus vulgaris</u>					
12	5.1004	3.3545	(7.3782 $\pm$ 10.1021)	(-.0830 $\pm$.2321)	0.836
<u>Pseudomonas aeruginosa</u>					
12	0.8458	8.8804	(7.3886 $\pm$ 16.4367)	(-.0550 $\pm$.3776)	0.458
<u>Serratia marcescens</u>					
12	1.4244	8.2050	(7.5455 $\pm$ 15.7993)	(-.0686 $\pm$.3630)	0.587

Table A-56

Reduction statistics of enteric bacteria species in filtrate from Chlorella vulgaris at mid-log growth phase. Series VII.

<u>N</u>	<u>S_H^2/S_r^2</u>	<u>S_r^2</u>	<u>b</u>	<u>k</u>	<u>R</u>
<u>Alcaligenes faecalis</u>					
14	8.1485	2.2109	(7.0826 $\pm$ 8.2012)	(-.0852 $\pm$.1884)	0.891
<u>Enterobacter aerogenes</u>					
14	11.8899	0.8985	(5.9278 $\pm$ 5.2283)	(-.0656 $\pm$.1201)	0.922
<u>Escherichia coli</u>					
14	6.2986	1.2075	(7.0093 $\pm$ 6.0610)	(-.0553 $\pm$.1392)	0.863
<u>Proteus vulgaris</u>					
14	14.888	0.9550	(6.5244 $\pm$ 5.3902)	(-.0757 $\pm$.1238)	0.937
<u>Pseudomonas aeruginosa</u>					
14	3.6679	3.1607	(7.2067 $\pm$ 9.8060)	(-.0683 $\pm$.2253)	0.786
<u>Serratia marcescens</u>					
14	2.6636	3.8659	(6.5441 $\pm$ 10.8448)	(-.0644 $\pm$.2491)	0.727

Table A-57

Reduction statistics of enteric bacteria species in filtrate from Scenedesmus obliquus at mid-log growth phase. Series VII.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
14	91.4609	0.0285	(8.8573 $\pm$.9313)	(-.0324 $\pm$.0214)	0.989
<u>Enterobacter aerogenes</u>					
14	109.62	0.0585	(8.9597 $\pm$ 1.3346)	(-.0508 $\pm$.0307)	0.991
<u>Escherichia coli</u>					
14	51.6465	0.0773	(8.4025 $\pm$ 1.5335)	(-.0401 $\pm$.0352)	0.981
<u>Proteus vulgaris</u>					
14	1.3987	0.4076	(8.2736 $\pm$ 3.5216)	(-.0151 $\pm$.0809)	0.583
<u>Pseudomonas aeruginosa</u>					
14	16.5995	0.4526	(8.0305 $\pm$ 3.7108)	(-.0550 $\pm$.0852)	0.943
<u>Serratia marcescens</u>					
14	5.1187	5.1345	(8.3673 $\pm$ 3.9523)	(-.0325 $\pm$.0908)	0.836

Table A-58

Reduction statistics of pathogenic bacteria species with Anabaena cylindrica. Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	222.0690	.1189	(6.0783 $\pm$.3755)	(-.0751 $\pm$.0098)	.9737
<u>Salmonella typhosa</u>					
8	11.0652	1.5269	(6.6067 $\pm$ 1.3458)	(-.0601 $\pm$.0351)	.6484
<u>Shigella paradysenteriae</u>					
8	95.2742	.2458	(6.8035 $\pm$.5399)	(-.0707 $\pm$.0141)	.9408
<u>Shigella dysenteriae</u>					
8	106.4579	.2418	(6.7365 $\pm$.5356)	(-.0742 $\pm$.0139)	.9466
<u>Vibrio comma</u>					
8	52.2653	.2336	(5.1157 $\pm$.5265)	(-.0511 $\pm$.0137)	.8970

Table A-59

Reduction statistics of pathogenic bacteria species with Anacystis nidulans.
Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	88.4104	.3737	(7.3962 $\pm$.6658)	(-.0840 $\pm$.0174)	.9364
<u>Salmonella typhosa</u>					
8	87.6496	.3064	(6.3929 $\pm$.6028)	(-.0758 $\pm$.0157)	.9359
<u>Shigella paradysenteriae</u>					
8	36.2172	1.2425	(6.6402 $\pm$ 1.2140)	(-.0981 $\pm$.0317)	.8579
<u>Shigella dysenteriae</u>					
7	146.9488	.2260	(6.8716 $\pm$.5993)	(-.1249 $\pm$.0208)	.9671
<u>Vibrio comma</u>					
7	66.3376	.3186	(5.2523 $\pm$.7116)	(-.0997 $\pm$.0247)	.9299

Table A-60

Reduction statistics of pathogenic bacteria species with Gloeocapsa alpicola.
Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	10.0872	2.0012	(7.5863 $\pm$ 1.5407)	(-.0657 $\pm$.0401)	.6270
<u>Salmonella typhosa</u>					
8	57.9672	.2999	(5.6856 $\pm$.5965)	(-.0609 $\pm$.0156)	.9062
<u>Shigella paradysenteriae</u>					
8	341.4663	.0948	(6.5899 $\pm$.3353)	(-.0832 $\pm$.0087)	.9827
<u>Shigella dysenteriae</u>					
8	250.8821	.1036	(5.8648 $\pm$.3505)	(-.0745 $\pm$.0091)	.9766
<u>Vibrio comma</u>					
8	19.9350	1.3396	(6.2735 $\pm$ 1.2606)	(-.0755 $\pm$.0329)	.7687

Table A-61

Reduction statistics of pathogenic bacteria species with Oscillatoria chalybia.
Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	14.8942	1.1813	(6.6241 $\pm$ 1.1837)	(-.0613 $\pm$.0309)	.7128
<u>Salmonella typhosa</u>					
8	11.2542	1.1372	(5.5874 $\pm$ 1.1614)	(-.0523 $\pm$.0303)	.6523
<u>Shigella paradysenteriae</u>					
8	15.7010	1.3518	(6.3148 $\pm$ 1.2663)	(-.0673 $\pm$.0330)	.7235
<u>Shigella dysenteriae</u>					
8	61.3114	.3928	(6.2078 $\pm$.6826)	(-.0717 $\pm$.0178)	.9109
<u>Vibrio comma</u>					
8	228.8732	.0834	(5.1152 $\pm$.3146)	(-.0639 $\pm$.0082)	.9745

Table A-62

Reduction statistics of pathogenic bacteria species with Oscillatoria formosa.
Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	67.3622	.4893	(6.2018 $\pm$.7618)	(-.0839 $\pm$.0199)	.9182
<u>Salmonella typhosa</u>					
8	206.1572	.1061	(5.2634 $\pm$.3547)	(-.0684 $\pm$.0093)	.9717
<u>Shigella paradysenteriae</u>					
8	291.2393	.0623	(5.3232 $\pm$.2718)	(-.0622 $\pm$.0071)	.9798
<u>Shigella dysenteriae</u>					
8	37.9589	.5839	(5.0350 $\pm$.8323)	(-.0688 $\pm$.0217)	.8635
<u>Vibrio comma</u>					
8	84.3495	.2766	(5.0534 $\pm$.5728)	(-.0706 $\pm$.0149)	.9336

Table A-63

Reduction statistics of pathogenic bacteria species with Phormidium faveolarum. Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	209.2254	.1396	(6.3641 $\pm$.4069)	(-.0790 $\pm$.0106)	.9721
<u>Salmonella typhosa</u>					
8	35.9760	.4714	(4.8470 $\pm$.7478)	(-.0602 $\pm$.0195)	.8571
<u>Shigella paradysenteriae</u>					
8	72.4309	.4044	(5.5891 $\pm$.6926)	(-.0791 $\pm$.0181)	.9235
<u>Shigella dysenteriae</u>					
8	48.7067	.4307	(5.1532 $\pm$.7147)	(-.0670 $\pm$.0186)	.8903
<u>Vibrio comma</u>					
8	59.2853	.3413	(4.6406 $\pm$.6363)	(-.0658 $\pm$.0166)	.9081

Table A-64

Reduction statistics of enteric bacteria in algal growth medium under anaerobic conditions.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Alcaligenes faecalis</u>					
12	1.089	.7497	(4.2661 $\pm$ 1.0626)	(-.0131 $\pm$.0253)	.179
<u>Enterobacter aerogenes</u>					
12	16.338	.3617	(6.0776 $\pm$.7381)	(-.0352 $\pm$.0175)	.7657
<u>Escherichia coli</u>					
12	189.839	.0604	(6.8443 $\pm$.3016)	(-.0490 $\pm$.0072)	.9743
<u>Proteus vulgaris</u>					
12	.738	1.1097	(4.7693 $\pm$ 1.2928)	(-.0131 $\pm$.0307)	.1287
<u>Pseudomonas aeruginosa</u>					
12	6.010	.7858	(5.7946 $\pm$ 1.0879)	(-.0315 $\pm$.0259)	.5459
<u>Serratia marcescens</u>					
12	111.430	.1359	(7.5824 $\pm$.4524)	(-.0563 $\pm$.0108)	.9571

Table A-65

Reduction statistics of pathogenic bacteria species in algal growth medium under anaerobic conditions.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
12	2.0283	1.0080	(5.2320 $\pm$ 1.2322)	(-.0207 $\pm$.0293)	.2886
<u>Salmonella typhosa</u>					
12	4.2477	.8056	(4.6221 $\pm$ 1.1016)	(-.0268 $\pm$.0262)	.4593
<u>Shigella dysenteriae</u>					
12	46.3827	.2490	(6.5081 $\pm$.6124)	(-.0492 $\pm$.0146)	.9027
<u>Shigella paradysenteriae</u>					
12	1.2762	1.4087	(4.2391 $\pm$ 1.4567)	(-.0194 $\pm$.0346)	.2033
<u>Vibrio comma</u>					
12	2.4089	.5228	(4.1682 $\pm$.8874)	(-.0162 $\pm$.0211)	.3251

Table A-66

Reduction statistics of pathogenic bacteria in presence of culture of four green algae species. Bacteria added to algae when in their mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
12	35.0416	.3373	(5.0683 $\pm$ 1.0587)	(-.1553 $\pm$.0617)	.9211
<u>Salmonella typhosa</u>					
12	37.5767	.3051	(5.8014 $\pm$.8522)	(-.1156 $\pm$.0402)	.9038
<u>Shigella paradysenteriae</u>					
12	46.6440	.3042	(5.7432 $\pm$ 1.0055)	(-.1702 $\pm$.0586)	.9396
<u>Shigella dysenteriae</u>					
12	48.0406	.1846	(5.4882 $\pm$.7831)	(-.1345 $\pm$.0457)	.9412
<u>Vibrio comma</u>					
12	41.3008	.2528	(5.0728 $\pm$.9165)	(-.1460 $\pm$.0535)	.9323

Table A-67

Reduction statistics of pathogenic bacteria in presence of culture of six blue-green algae species. Bacteria added to algae when in their mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
12	34.9980	.3504	(5.6754 $\pm$.7463)	(-.0759 $\pm$.0259)	.8750
<u>Salmonella typhosa</u>					
12	40.8310	.3134	(4.9758 $\pm$.7058)	(-.0775 $\pm$.0244)	.8909
<u>Shigella paradysenteriae</u>					
12	36.7898	.1841	(4.2882 $\pm$.5409)	(-.0564 $\pm$.0187)	.8804
<u>Shigella dysenteriae</u>					
12	12.6987	.6502	(5.8225 $\pm$ 1.4382)	(-.1124 $\pm$.0673)	.7605
<u>Vibrio comma</u>					
12	53.4203	.1396	(4.9777 $\pm$.5765)	(-.0933 $\pm$.0272)	.9303

Table A-68

Reduction statistics of pathogenic bacteria species in algal growth medium Controls.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	7.084	2.936	(4.7225 $\pm$ 1.6467)	(-.0622 $\pm$.0454)	.5414
<u>Salmonella typhosa</u>					
8	75.1391	.3737	(5.3975 $\pm$.6658)	(-.0775 $\pm$.0174)	.92605
<u>Shigella paradysenteriae</u>					
8	26.9832	.9442	(5.0349 $\pm$ 1.0583)	(-.0738 $\pm$.0276)	.8181
<u>Shigella dysenteriae</u>					
8	30.5534	.8124	(5.0675 $\pm$.9817)	(-.0728 $\pm$.0256)	.8359
<u>Vibrio comma</u>					
8	35.4679	.5158	(4.3030 $\pm$.7822)	(-.0625 $\pm$.0204)	.8553

Table A-69

Reduction statistics of pathogenic bacteria species with Ankistrodesmus braunii. Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	53.4130	.4618	(5.2557 $\pm$.7401)	(-.0726 $\pm$.0193)	.8990
<u>Salmonella typhosa</u>					
8	50.0659	.4051	(4.5382 $\pm$.6932)	(-.0658 $\pm$.0181)	.8930
<u>Shigella paradysenteriae</u>					
8	32.6928	.7621	(4.9435 $\pm$.9508)	(-.0730 $\pm$.0250)	.8449
<u>Shigella dysenteriae</u>					
8	25.4007	.9202	(4.7347 $\pm$ 1.0448)	(-.0707 $\pm$.0272)	.8089
<u>Vibrio comma</u>					
8	62.7151	.2627	(4.1532 $\pm$.5582)	(-.0593 $\pm$.0146)	.9127

Table A-70

Reduction statistics of pathogenic bacteria species with Chlorella pyrenoidosa. Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
6	16.7589	1.0565	(5.0966 $\pm$ 1.3713)	(-.0950 $\pm$.0495)	.8073
<u>Salmonella typhosa</u>					
6	29.6214	.6437	(5.4513 $\pm$ 1.0704)	(-.0986 $\pm$.0386)	.8810
<u>Shigella paradysenteriae</u>					
6	66.4033	.2931	(5.1800 $\pm$.7223)	(-.0996 $\pm$.0261)	.9432
<u>Shigella dysenteriae</u>					
6	11.8522	1.1679	(4.4327 $\pm$ 1.4418)	(-.0840 $\pm$.0520)	.7477
<u>Vibrio comma</u>					
6	17.2831	.6330	(4.3459 $\pm$ 1.0614)	(-.0747 $\pm$.0383)	.8121

Table A-71

Reduction statistics of pathogenic bacteria species with Chlorella vulgaris. Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
7	16.3117	1.2757	(4.6525 $\pm$ 1.2950)	(-.0669 $\pm$.0334)	.7654
<u>Salmonella typhosa</u>					
7	13.2037	1.1533	(4.5957 $\pm$ 1.2314)	(-.0572 $\pm$.0317)	.7253
<u>Shigella paradysenteriae</u>					
7	15.7464	1.1842	(4.1637 $\pm$ 1.2477)	(-.0633 $\pm$.0322)	.7590
<u>Shigella dysenteriae</u>					
7	29.2807	.7786	(4.7370 $\pm$ 1.0117)	(-.0700 $\pm$.0261)	.8541
<u>Vibrio comma</u>					
7	10.9643	.9153	(3.5452 $\pm$ 1.0970)	(-.0465 $\pm$.0283)	.6868

Table A-72

Reduction statistics of pathogenic bacteria species with Scenedesmus obliquus. Bacteria added to algae in mid-log growth phase.

N	S_H^2/S_r^2	S_r^2	b	k	R
<u>Salmonella paratyphi</u>					
8	34.3155	.9453	(6.2250 $\pm$ 1.0590)	(-.0833 $\pm$.0276)	.8512
<u>Salmonella typhosa</u>					
7	13.7076	.7617	(4.5996 $\pm$ 1.1003)	(-.0700 $\pm$.0381)	.7327
<u>Shigella paradysenteriae</u>					
7	27.1390	.8834	(6.1021 $\pm$ 1.1849)	(-.1061 $\pm$.0411)	.8444
<u>Shigella dysenteriae</u>					
7	18.2956	1.0167	(5.3369 $\pm$ 1.2712)	(-.0935 $\pm$.0440)	.7854
<u>Vibrio comma</u>					
7	13.4125	1.2051	(4.9428 $\pm$ 1.3843)	(-.0872 $\pm$.0480)	.7285

APPENDIX B

BACTERIOLOGICAL DATA FROM LABORATORY AND
FIELD WASTE STABILIZATION POND STUDIES

Table B-1. Total Bacteria Densities In Laboratory Scale Waste Stabilization Ponds, As $\log_{10}/\text{ml.}$

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#5	#6	#7	#8	#9	#10	#11
7- 3-69	6.72673	6.66346	5.97081	5.54407	5.10380	3.32593	5.65992	5.65992	4.88081	6.41119	5.53593	5.22011	4.69940
7- 7-69	6.46613	5.97772*	5.50106*	5.08991	6.12222	4.92942*	5.11227*	5.68574*	5.68574*	4.00000*	5.23045	6.65002	6.07188*
7- 9-69	7.05757	6.99717	6.72148	6.90227	5.96190	6.81023	6.58743	5.99388	5.99388	5.48714	5.64444	6.13928	6.28780
7-11-69	7.34782	7.07372	6.41330	5.78426	5.98520	6.60152	5.69174	6.53553	5.43377	5.32919	5.58546	5.62273	5.94052
7-14-69	7.19576	6.10380	4.65369	4.79727	5.50718	5.04115	5.47857	4.64836	5.32919	5.32919	5.49406	5.24613	5.20276
7-16-69	7.49066	6.79239	5.01072	5.05777	5.44248	4.59660	5.68679	4.97058	4.97058	6.02794	5.08955		3.87506
7-18-69	8.52022	6.79379	4.95425	4.91803	5.48572	4.97405	6.04139	4.53782	4.53782	5.62014	6.38382	5.21617	4.58433
7-23-69	7.92505	7.47276	6.50827		6.20352	5.34193	5.79344	5.07555	5.07555	5.67486	6.44739	5.71012	4.38075
7-25-69	7.79449	6.26834	5.44871	5.19728	5.04922	4.34133	5.94374	5.98989	5.98989	5.42488	5.31597	5.77815	4.09377
7-29-69	7.12385	6.28948*	5.01589*	4.75587	5.13672	4.33445*	5.22272*	5.48180*	5.48180*	5.51455*	5.79623	5.43933	4.98453*

*Inoculation with laboratory cultures: 7-7 and 7-29 with E. c., Pseud., and Serr.

Table B-2. Total Bacteria Densities In Laboratory Scale Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station--		#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
	Row	#1										
8- 4-69	7.32531	6.26411	5.12988	4.69152	5.30211	6.19209	5.13751	5.63220	5.45255	5.85643	4.94349	4.96848
8- 6-69	7.66229	5.62685	4.32736	4.05115	3.97428	4.98080	5.56732	5.33244	5.08279	4.96497	4.75397	4.51455
8- 8-69	6.78013	4.74819	6.95624	6.81471	7.21885	7.60590	8.55781	8.46310	7.60487	8.38462	7.65715	7.34922
8-11-69	6.74036	5.67669	4.19033	4.31175	4.61805	4.07278	5.67669	5.04139	5.29003	5.37107	5.35218	4.75967
8-13-69	7.04630	6.17099	5.29667	4.63347	5.40184	4.15381	5.88804	5.09552	5.08458	5.13988	5.26717	5.09691
8-15-69	6.96379	6.24304	5.36549	5.23553	5.02531	4.48714	6.29831	5.16732	5.53782	5.73139	4.93197	5.70948
8-18-69	7.42243	5.47712	4.75397	4.45864	5.12711	4.48572	6.13513	4.92428	5.39226	5.46613	4.85126	5.13830
8-20-69	7.12710	6.02531	3.98677	4.81624	4.49136	4.29994	6.30428	4.07188	5.31175	5.41497	5.86332	5.09342
8-22-69	7.51851	6.36680	5.20412	5.94694		4.61278	6.69329	5.49136	5.70372	5.72937	5.93952	5.54064
8-26-69	6.87216	5.30103	4.16137	4.52504	4.43537	4.11227	4.79588	4.70757	4.57113	4.68350	5.02119	4.59934

Table B-3. Total Coliform Bacteria Densities In Laboratory Scale Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
7-3-69		4.88930	4.39794		2.08279	0.74036	3.71642	0.39794	3.87506	3.54407	2.00000	
7-7-69	5.14613	3.92942*	*				4.39902*	*	2.00000*	3.97772	2.30103	*
7-9-69	4.69907	5.07918	4.55630	5.59106	4.30103	4.90714	3.96614	4.67482			4.00000	3.26682
7-11-69	5.60746	5.00000	5.36173	4.50515	5.06070	4.74036	4.30103	4.60206	4.14613	4.38021	2.14922	
7-14-69		5.07918	3.13830	3.62839	3.90309	3.00000	3.00000	3.77815	3.15381	3.12222	3.56526	4.23045
7-16-69	6.81258	6.32222			4.13033							
7-18-69	5.87216	6.43537	3.79588	2.81291	3.79588		4.63599	3.75967	4.76343	4.76080	4.17609	1.57978
7-23-69	6.66039	4.70329	0.97772	0.17609	0.17609	4.31175	3.72632	4.25539	3.27875	2.87040	4.49693	2.13033
7-25-69	5.62839	4.73679					3.87535		2.39750	2.95904	2.51587	
7-29-69	6.01807	4.28443*	*			*	2.95036*	*	2.72815*	2.79571	2.63246	*

*Inoculation with laboratory cultures: 7-7 and 7-29 with E. c., Pseud., and Serr.

Table B-4. Total Coliform Bacteria Densities In Laboratory Scale Wastes
Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#5	#7	#8	#9	#10	#11
8- 4-69	5.19866	3.40449	1.72222	0.54407		3.00432	2.02632	2.20140	2.05881	1.80787	2.09078	1.74624
8- 6-69	5.85126		1.07918	0.84510	0.30103	1.97543		1.23045		1.79934	0.69897	0.90309
8- 8-69	5.75587	4.06633	0.30103	0.30103		1.02110	2.95424	1.06446	3.61278	0.95424	1.92428	
8-11-69	5.71600	3.81291	1.49136	2.32222		0.81291	3.17609	0.30103	3.06446			
8-13-69	5.78176	4.39794										
8-15-69	5.57978	4.65321	0.77815			1.25527	1.99123	1.51188	3.51851	3.27875	3.23045	2.30103
8-18-69	5.08279	4.37566		0.00000		3.30103	4.65321	3.17609	3.69897	3.50515	3.14613	1.76343
8-20-69	6.10551	4.51521		0.00000	0.00000	0.90309	3.29003	1.72428	2.38021	4.17609	4.53148	4.43136
8-22-69	5.86332	3.84510	0.17609	0.00000		1.71391	2.95424		3.14613	3.27875	3.11394	0.17609
8-26-69	5.72222	3.84510		0.00000		1.71181	2.52114	0.00000	3.17609	3.14613	3.32736	0.30103
						2.04238	2.49554	0.17609	2.77815	2.51055	2.13672	1.07918

Table B-5. *Escherichia coli* Densities In Laboratory Scale Waste
Stabilization Ponds, As $\text{Log}_{10}/\text{ml}$.

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
7- 3-69		4.54407										
7- 7-69	4.74036	3.74036*	*			*	3.00496*	*	*		3.00000	*
7- 9-69	4.69954	5.07918	4.55630	5.59660	4.30103	4.90687	3.96614	3.67685			4.00000	3.03080
7-11-69	4.69897	5.36173	4.38021	4.84510	5.74036	4.30103	4.39794					1.68124
7-14-69	4.95424	3.13033	3.62839	3.90309	3.00000	3.00000	3.77815	3.15381	3.12222		3.56526	4.07918
7-16-69	5.49381	6.29447	3.00000		3.17609	4.30103	4.02119	3.47712	3.17609	3.60206	3.90309	3.00000
7-18-69	5.27875	5.06004					4.11394	2.74036	3.84510	4.04115	3.77815	1.54407
7-23-69	6.49206	4.86332	0.00000			3.60206	3.21748	2.92942	2.03443	0.00000	4.44560	1.11394
7-25-69	5.06070	4.11394							1.14613	2.81291	2.60206	
7-29-69	5.41497	3.62325*	*			*	2.41664*	*	3.17609*	1.89487	2.02531	*

*Inoculation with laboratory cultures: 7-7 and 7-29 with E. c., Pseud., and Serr.

Table B-6. *Escherichia coli* Densities in Laboratory Scale Waste
Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station--		#3	#4	#5	#6	#7	#8	#9	#10	#11
	Raw	#1									
8- 4-69	4.95785	2.20276	0.54407		3.00453	1.90309	2.12385	2.02531	1.14613	2.09078	1.74624
8- 6-69	4.37107		0.60206		1.97543		0.87506		1.30103		0.90309
8- 8-69	4.14613	3.27875	0.00000		0.69897	2.07918	0.84510	3.00000		1.11394	
8-11-69	3.65321				0.30103	3.07918	0.00000	3.84510	3.92942	2.69897	2.30103
8-13-69	5.21748	3.81291				1.30103	0.00000	2.60206	2.54407	2.30103	
8-15-69	4.92942	4.00000			0.54407	0.47712			2.00000	2.77815	
8-18-69	5.55023	3.54407	0.00000		0.84510	2.69897	1.70969	2.92942	2.84510	2.95424	0.69897
8-20-69	5.27875	4.14613			1.70969	2.54407		2.47712	2.65321	2.47712	0.00000
8-22-69	5.26717	3.54407	0.00000		1.71181	1.73640		2.30103	2.79588	2.81291	0.00000
8-26-69	5.00432	3.39794			2.03941	0.39794		2.30103	1.73838	1.71181	

Table B-7. *Pseudomonas aeruginosa* Densities In Laboratory Scale
Waste Stabilization Ponds, As $\log_{10}/\text{ml}$.

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
7- 3-69			4.30103			0.00000			4.00000	3.77815	3.74036	
7- 7-69		*	*			*	*	*	*			*
7- 9-69			5.97772	5.97772	5.17609	5.34242		3.00000				
7-11-69		4.00000	5.30103		3.87506	4.92942	3.00000	3.81291		2.00000	4.00000	3.00000
7-14-69												
7-16-69												
7-18-69								4.00000				
7-23-69												
7-25-69						*	*	*	*	*	*	*
7-29-69		*	*	*	*	*	*	*	*	*	*	*

*[Inoculation with laboratory cultures: 7-7 and 7-29 with E. c., Pseud., and Serr.

Table B-8. *Pseudomonas aeruginosa* Densities In Laboratory Scale
Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
8- 4-69			4.17609				3.30103	3.69897		3.00000	3.47712	
8- 6-69			3.00000						3.00000			
8- 8-69												
8-11-69												
8-13-69												
8-15-69					3.00000					3.00000		3.84510
8-18-69											3.00000	3.00000
8-20-69												3.00000
8-22-69			3.00000	3.77815		2.30103				4.74036		
8-26-69	5.30103		3.00000	3.74036	2.90309	2.79588		3.00000	3.00000	3.39794		

Table B-9. *Serratia marcescens* Densities In Laboratory Scale
Waste Stabilization Ponds, As $\log_{10}/\text{ml}$.

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
7- 3-69												
7- 7-69		*	*			*	*	*	*			*
7- 9-69			5.64836	5.53782	4.73038	4.74036	3.77815	3.90309		3.77815		
7-11-69			4.75967	3.47712							4.00000	
7-14-69			2.81291	2.92942								4.30103
7-16-69												
7-18-69				2.00000					4.90309			
7-23-69												
7-25-69												
7-29-69		*	4.12222*	4.24304	3.95424	*	3.00000*	4.30103*	*		4.00000	*

*Inoculation with laboratory cultures: 7-7 and 7-29 with E. c., Pseud., and Serr.

Table B-11. Chromagen Densities In Laboratory Scale Waste Stabilization Ponds, As $\log_{10}/\text{ml}$.

Date	Sample Station-- Raw	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11
7- 3-69		5.36642	5.29003	4.74036	4.38021		4.70757	4.09691	5.62325	3.95424	4.52504	4.13033
7- 7-69						4.00000					5.65992	
7- 9-69	5.07004	5.45484					6.02531	5.74036	4.96332	5.07555	5.74710	
7-11-69	5.84510	5.32222	5.54407	4.64836	5.37475	6.26245	5.01599	5.91566	4.74429	5.03743	5.07918	5.63548
7-14-69			3.87506	3.74036	4.06070		3.74036	4.00000	2.81291	3.66978	4.10551	4.30103
7-16-69			3.84510	3.77815	4.27875		4.77761	3.79588	3.19033	3.30125		
7-18-69												
7-23-69	6.06070	5.47712	4.52114	3.77815	5.35781	4.35784	5.09342	4.07918	4.51851	6.00065	4.91116	2.55023
7-25-69	6.63849		3.47712	3.00000			4.41497	4.34242	4.60206	3.47712	4.77815	0.81291
7-29-69				3.47712	4.27875	2.69897	3.87506	4.46613	4.63347	4.77452		3.19033

Table 8-13. Total Bacteria Densities In Waste Stabilization Ponds, As $\log_{10}/\text{ml}$.

Date	Sample Station--		#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
	#1	#2										
6-4-69	6.34242	6.35210		6.51455		4.98677	6.15534		5.66276			
6-5-69	6.44716	6.57478*	6.30103	5.92428*	5.32222	5.07918	5.66276	5.50206				
6-6-69	6.73560	6.69897	7.00000	6.14922	5.43136	5.69020	6.28780	5.59897	5.56820			
6-9-69	6.70842	6.02119	6.67394	6.20140	6.58883	5.74036	6.65610	5.19866	4.84510			
6-11-69	6.70415	6.38202	6.35025	4.81954	5.55630	4.56820	5.42975	5.39794	4.77815	5.80482	5.79029	
6-13-69	6.69984	6.58659	6.28556	3.00000	5.29667	4.79934	5.45025	5.41497	4.94448	6.49136	6.25285	
6-16-69	6.59550	5.98677	5.95904	4.74819*	5.67025	4.74036	5.28330	5.34830	4.44716	4.44716	5.29003	5.34242
6-18-69	6.96100	5.72673	5.90472	5.06819	5.67302	5.24304	5.17319	5.29885	3.60206	5.17898	4.79239	3.30103
6-20-69		6.46240	6.29885	4.60206	4.47712	4.27875	*		3.00000			3.77815
6-23-69		6.82217	6.48430			4.57978	3.00000		4.85126	*		3.60206
6-25-69						3.95424			3.04139			3.87506
6-27-69	6.69108	6.65706	6.64246	3.14613	4.46850	3.20412	3.57978	3.50515	3.20412	5.46538	5.65992	3.89763
6-30-69	7.03262	6.35458	6.34044	6.96656	4.38758	3.25696	4.57980	5.70672	3.66783	5.65300	5.78247	4.48195

*Inoculation with laboratory cultures: (6-5; E. c., Pseud.) (6-16; E. c., Pseud., Serr.) (6-19; shown as 6-20; E. c., Pseud., Serr.) (6-23; E. c., Pseud., Serr.)

Table 8-14. Total Bacteria Densities In Waste Stabilization Ponds, As $\text{Log}_{10}/\text{ml}$.

Date	Sample Station-- #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
7-2-69	6.73878	6.98644	6.93865	5.37220	5.48853	4.10072	5.14426	5.23259	5.18611	5.72835	5.76530	5.30604
7-7-69	7.29612	7.35362	7.19590	5.43616	5.58092	3.58192	5.21484	4.98227	4.74819	5.22660	5.61013	5.07004
7-9-69	6.86629	6.36605	7.03993	3.87344	5.42922	5.47787	5.17342	5.40747	4.87484	6.27140	6.63624	5.74321
7-11-69	7.34587	7.27646	7.53656	5.36577	6.09412	5.28780	6.64147	6.22154	5.88053	6.21163	6.37658	5.85137
7-16-69	7.19576	7.37767	7.10806	5.59106	5.78319	4.16443	5.51521	5.38471	4.52827	6.44091	6.38292	5.96308
7-18-69	7.49066	6.60016	6.03523	6.63829	6.48053	6.18064	6.59555	6.35005	5.33011	6.82086	6.62428	6.72926
7-21-69	8.52088	7.96497	8.25600	5.77706	6.19089	4.86540	6.33163	6.18227	5.25139	6.38739*	7.22789	6.43553
7-23-69	7.92505	7.19033	7.34635	5.53013	6.73632	6.02735	6.50853	6.57119	5.79955	7.12548	6.93717	6.86608
7-25-69	7.79449	6.82445	7.19451	7.28319	7.17713	6.26174	6.28171	6.50127	5.44754	6.72016	7.13815	5.39094
7-29-69	7.12385	7.27646	6.56820	5.20548	5.61262	4.15987	5.29115*	5.36949	4.24055	6.08814	6.14760	5.24920
7-31-69	7.22272	6.92298	7.14301	5.77379	5.52504	4.45102	5.33746	5.26600	2.94201	6.02325	5.56229	4.92169

*Inoculation with laboratory cultures: 7-21 and 7-29 with E. C., Pseud., and Serr.

Table 8-15. Total Bacteria Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station--											
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
8- 4-69	7.33244	7.24981	6.98000	4.67210	6.33496	5.63246	5.62480	5.56526	5.04336	6.62660	5.63849	4.97313
8- 6-69	7.66229	6.93069	6.99344	6.12215	5.99100	5.55991	5.58574	5.79934	5.37794	5.55961	5.92634	4.98453
8- 8-69	7.05207	7.20880	7.29170	6.40140	6.63849	5.49136	7.20412	6.44770	5.93197	6.46117	6.35338	5.66229
8-13-69	7.04630	7.08636	7.08189	6.88550	6.82102	4.96379	7.05300	6.61316	5.78645	6.34586	6.25467	5.15076
8-15-69	6.96379	7.22789	7.48996	7.28499	7.14613		7.38828	6.84510	5.93827	6.71904	6.66745	6.12548
8-18-69	7.42243	6.91116	7.29447	6.80702	6.87938	6.13909	7.15503	6.73739	6.24748	6.55023	6.87795	5.83727
8-20-69	7.12710	7.22531	7.26186	6.46165	6.71391	6.37475	6.81067	5.79831	5.64738	5.93827	6.02531	5.60959
8-22-69	7.51851	7.29115	7.29336	7.05018	6.87520	6.89708	7.42854	7.25768	6.47276	6.89070	6.30049	6.56926
8-26-69	6.87216	6.84819	6.84973	6.67440	6.54777	5.72428	6.16584	5.72222	5.59988	5.54407	5.55328	5.31755

Table B-16. Total Coliform Bacteria Densities In Waste Stabilization Ponds, As $\log_{10}/\text{ml}$.

Date	Sample Station--		#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
6- 4-69		5.69897		5.60206			5.47712					
6- 5-69	5.47712	5.30103*	5.00000	4.20412*	4.11394	3.90811	4.54407	4.34242	3.77815			
6- 6-69	5.77815	5.60206	5.47712	4.17609	4.39794	2.80625	5.81889	3.90309				
6- 9-69	5.77670	5.70569	5.83569	5.15836	3.69897	1.74115	4.88081	3.47712				
6-11-69	5.98137	5.00000	4.81554		3.00000		3.92942	4.14613		4.74819	4.57403	
6-13-69	5.77815	6.21484	4.93450		3.17609	2.93450		4.25527		4.83885	4.43136	
6-16-69	5.90309	4.77085	4.66276	2.69897*	4.35794	1.63347	3.84510	3.69897		3.74036	3.87506	2.69897
6-18-69	5.02938	5.17319	5.17609	0.69897	1.86923	1.59106	2.71349	3.19285	0.00000	3.37840	2.00043	1.04139
6-20-69	6.23045	5.04139	5.04139	2.20140	1.64345	1.72428	3.00000*	3.84510		3.84510	3.60206	0.97772
6-23-69	5.75587	4.92942	5.43136	4.90309		1.86332	1.13033	0.60206	4.17609	*	3.00000	
6-25-69	5.80618	4.65321	4.96848	2.40483	0.69897		2.88053	1.32222	1.39794	3.03342	2.53020	0.77815
6-27-69	6.51983	4.77815	4.84510	0.69897	1.25527	1.87216	3.04532	3.18752		2.94349	3.48430	0.77815
6-30-69	5.85733	4.60206	4.77815	0.00000	0.54407	1.92942	1.44716	0.45788		0.54407	2.95665	0.30103

*Inoculation with laboratory cultures: (6-5: E. c., Pseud.) (6-16: E. c., Pseud., Serr.) (6-19: shown as 6-20: E. c., Pseud., Serr.) (6-23: E. c., Pseud., Serr.)

Table B-17. Total Coliform Bacteria Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station-- #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
7- 2-69	5.62325	4.90300	5.07004	2.70136	0.02119		2.75797	2.71204	0.47712	3.42704	2.77670	2.70286
7- 7-69	6.12304	5.19728	4.74036	0.69897	2.70265	0.30103	3.49534	3.19770	0.60206	3.49631	2.80058	0.47712
7- 9-69	5.59934	5.77815	5.17609	0.60206	2.70243	0.54407	1.31175	3.84510	1.81291	3.69897	0.84510	1.17609
7-11-69	5.65321	5.27875	4.64098		1.21748	0.74036				2.03141	2.81291	
7-16-69	6.81258	5.24304	4.89900	2.94201	3.20412		4.02119	3.94939	1.00000			
7-18-69	5.87216	5.14922	4.89209	2.84261	3.92686		3.46240	3.55630	1.13033	4.48359	3.86332	3.90300
7-21-69	6.17464	4.96848	4.65801		0.00000		3.83727	3.47349	1.29003	*	3.90982	0.54407
7-23-69	6.66039	5.27068	5.51117	2.02735	2.13354	0.90309	4.01912	4.66978	0.30103	4.09342	3.11394	0.77815
7-25-69	5.62839	4.59660	4.94448	0.00000	2.84510		3.66745	3.74036	0.30103	3.37107	3.89487	1.24304
7-29-69	6.01807	4.29003	4.73838	0.00000	2.00000	0.47712	2.74036*	2.97772		1.90445	3.50174	0.47712
7-31-69	4.89209	5.05500	4.06633	2.00304		0.14613	3.31175	2.90309	0.90309	5.13354	3.19033	1.49831

*Inoculation with laboratory cultures: 7-21 and 7-29 with E. c., Pseud., and Serr.

Table B-18. Total Coliform Densities In Waste Stabilization Ponds, As $\log_{10}/\text{ml}$.

Date	Sample Station--											
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
8- 4-69	5.19866	4.99782	4.86332	0.30103	2.00000	1.30103	2.47712	2.30103	0.77815	3.13033	3.00000	0.77815
8- 6-69	5.85126	4.71809	4.53148	1.78176	2.87852	0.00000	3.51188	3.27875		2.81291	3.75967	
8- 8-69	5.75587	4.54407	4.92942	1.17609	2.88944	1.00000	3.99123	3.52504	1.00000	2.00647	4.59106	0.30103
8-13-69	5.78176	4.96142	4.69461	1.97658	2.55509	0.47712	4.11561	3.46982	0.90309	3.65321	3.60314	1.17609
8-15-69	5.57978	4.81790	4.88081	3.92169	3.47712	1.55630	3.82607	3.67210	1.72016	3.95424	4.14301	2.15076
8-18-69	6.08279	4.97081	3.72428	3.03141	3.09691	0.60206	3.96379	3.72222	0.65321	3.16137		1.71181
8-20-69	6.10551	4.92686	4.96142	2.15381	3.71809	2.47712	3.84354	3.89625	1.72016	3.63849	3.47712	2.01072
8-22-69	5.86332	4.90037	4.65801	2.00432	1.91116	0.00000	3.84819	3.34242	2.41664	3.61013	3.55630	1.78355
8-26-69	5.72222	5.07225	4.84819	3.13409	3.50379		3.29003	3.68124		3.24304	3.74233	2.50651

Table B-19. Escherichia coli Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station--		#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
	#1	#2										
6-4-69		5.30103										
6-5-69	5.00000	*		3.84510*	3.30103		4.04139	3.00000	3.00000			
6-6-69	5.00000	5.00000	5.00000				4.75587	3.75587				
6-9-69	5.23553	3.92942	4.06070	3.97772	3.30103		4.42813	2.69897				
6-11-69	4.81954	4.11394	4.46240				3.00000	3.39794		3.54407	3.47712	
6-13-69	5.00000	4.88195	4.34242		2.69897			3.81291		3.39794	3.00000	
6-16-69	5.39794	3.69897	3.39794	*			3.17609	3.17609		3.00000		
6-18-69	4.19033	5.03743	3.17609	0.30103					0.77815	1.46240	0.87506	0.54407
6-20-69	5.97772	4.84510	4.72428	1.89763	2.43457		*	3.60206	0.17609	1.69897*	3.47712	0.47712
6-23-69		4.54407	4.60206	0.69897			0.00000	0.39794	3.39794			
6-25-69	5.34242	4.00000	4.39794	0.60206	0.17609		2.40140	0.00000	0.17609	2.94448	1.54407	0.17609
6-27-69	5.67210	4.74036	4.77815	0.00000	0.47712		2.77085	3.02531		3.35218	2.77815	0.00000
6-30-69	5.58546	4.47712	4.65321	0.00000	0.30103		1.30103	1.54407		0.17609	1.99123	

*Inoculation with laboratory cultures: (6-5; E. c., Pseud.) (6-16; E. c., Pseud., Serr.) (6-19; shown as 6-20; E. c., Pseud., Serr.) (6-23; E. c., Pseud., Serr.)

Table B-20. *Escherichia coli* Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Sample Station--		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
Date													
7- 2-69	5.04139	4.17609	4.82930	0.30103	0.00000			1.46240	0.77815		2.89154	2.70906	0.60206
7- 7-69	5.46613	5.06070	4.30103	0.39794	0.47712	0.30103		3.24920	3.24834	0.00000	3.00000	1.60746	0.00000
7- 9-69	5.44248		5.00000				0.54407		3.30103		2.00647		
7-11-69		4.68970	3.30103								2.00647		
7-16-69	5.49381	4.69897	4.57403	2.00967	2.00000			3.63347	3.41078	0.30103	3.59660	3.67669	0.81291
7-18-69	5.27875	4.45102	4.41497	2.57692	2.00000			2.90309	3.04139	0.69897	3.43933	3.24304	
7-21-69	5.54407	4.75587	4.10551		0.00000			3.49136	3.50515	0.00000	*	3.03141	0.30103
7-23-69	6.49206	4.97772	4.58546	2.01599	1.90309	0.00000		3.78176		0.00000	3.65801	3.69897	
7-25-69	5.06070	3.92942	4.39794		2.00000			3.14613	2.90309	0.00000	2.81291	3.14613	0.30103
7-29-69	5.41497	4.13830	4.48430					3.47712*	2.54407		2.50103	2.84510	
7-31-69	4.67210	4.78533	3.66976					3.11394	2.77815		4.66276	2.97772	

*Inoculation with laboratory cultures: 7-21 and 7-29 with E. c., Pseud., and Serr.

Table 8-21. *Escherichia coli* Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station--											
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
8- 4-69	4.95785	4.66745	4.11394						0.30103	2.65321	2.84510	
8- 6-69	5.37107	4.27875	4.14613		0.47712	0.00000	3.20412	3.00000		2.69897	3.27875	
8- 8-69	5.14613	3.90309	4.25527	0.84510	1.72428	0.30103	3.23045	3.84510	0.30103	2.54407		
8-13-69	5.21748	4.51188	4.06691	1.75967	2.18184		2.92942	2.90309	0.00000	2.77815	2.65321	0.30103
8-15-69	4.92942	4.32736	4.16137	3.86332	2.84510	0.60206	3.20412	3.17609	1.25527	2.90309	2.92942	0.65321
8-18-69	5.55023	4.62066	3.43933	2.84510	2.82930		3.56229	3.33244	0.30103	2.95424		2.00000
8-20-69	5.27875	4.14613	4.20412	1.73640	2.00000		3.30103	2.81291	0.30103	3.06070	3.00000	0.00000
8-22-69	5.26717	4.37107	4.14613	0.17609	1.72428		3.26717	2.94201	1.70329	2.90309	2.88930	1.71809
8-26-69	5.00432	4.30643	4.00432	2.14535	2.49693		3.07918	3.04139	2.35218	2.91645	3.13830	0.77815

Table B-23. Pseudomonas aeruginosa Densities In Waste Stabilization Ponds, As $\text{Log}_{10}/\text{ml.}$

Date	Sample Station--		#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
	#1	#2										
7- 2-69			5.30103									3.00000
7- 7-69												
7- 9-69				0.69897	0.97772			0.00000				1.04139
7-11-69												
7-16-69						3.00000						
7-18-69												
7-21-69												
7-23-69												
7-25-69												
7-27-69												
7-29-69												

*Inoculation with laboratory cultures: 7-21 and 7-29 with E. c., Pseud., and Serr.

Table B-24. Pseudomonas aeruginosa Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station-- #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
8- 4-69											3.74036	
8- 6-69		5.30103		3.47712	3.00000							
8- 8-69			5.00000									
8-13-69	6.00000											
8-15-69		5.00000							3.09691		4.30103	3.17609
8-18-69									4.00000			
8-20-69												
8-22-69												
8-26-69	5.30103			4.00000				3.30103	3.74036			3.00000

Table B-25. Serratia marcescens Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station--			#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
	#1	#2											
6- 4-69													
6- 5-69													
6- 6-69													
6- 9-69													
6-11-69													
6-13-69													
6-16-69													
6-18-69						5.00000						3.00000	
6-20-69													
6-23-69													
6-25-69												3.60206	6.76716
6-27-69	5.00000					3.69897		0.30103	4.30103				
6-30-69							2.69914	*			0.30103		
										3.00000			

*Inoculation with laboratory cultures: 7-21 and 7-29 with E. C., Pseud., and Ser.

Table B-27. Chromagen Densities In Waste Stabilization Ponds, As Log₁₀/ml.

Date	Sample Station--		#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
6-30-69	5.17609	5.15381	5.60206	3.35392	3.00475	3.00303	3.00260	3.60206	1.73239	3.44404	3.47712	3.01452
7- 2-69	5.54407	5.39794	5.39794	4.38021			5.04532	4.33952		3.47712	3.97772	
7- 9-69	5.07004	6.11644	6.19451	2.70372	4.77452	5.01912	4.33415	4.51382	4.37493	5.92428	6.27300	4.20656
7-11-69	5.84510	6.96848	7.28103	5.17026	5.53593	4.87338	6.27875	4.38021	5.92763	5.35698	5.69020	5.26007
7-18-69		6.50515	5.77815	6.23465		5.65562	6.17826	5.92763	4.99454	6.30750	5.72835	5.63949
7-21-69	5.69897	5.60206	6.00000	3.00000				5.39794	4.40824	*		6.05500
7-23-69	6.06070	5.69897	5.90309	6.19866	6.74135	5.69858	6.08027	5.96755	5.40697	6.71809	6.59638	6.50583
7-25-69	6.63849	6.32222	6.63347	6.41747	6.86004	5.93044	5.91619	6.04001	4.83569	6.34044	6.71684	
7-29-69			0.00000	3.74086	2.54407		*	2.17609				4.65321
7-31-69	5.00000				3.00000	2.47712						

*Inoculation with laboratory cultures: 7-21 and 7-29 with E. c., Pseud., and Serr.

APPENDIX C
PROGRAM BETA FORMAT


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000002      PROGRAM RFTA(INPUT,OUTPUT)                                000
000002      DIMENSION INDEX(14),Y(400),X(20,400),W(400),TABLE(34,3),A(20,20), 001
000002      1YX(20),B(20),CDCT(20,20),RDCY(20),CINV(20,20),NSUB(20),QP(20), 002
000002      2CCVAR(20,20),SUI(20),PSTAR(20),FORM2(5), 003
000002      3FCRW(7),CA(20,20),C(20,20),UARI(400),YHAT(400) 004
000002      DIMENSION YHAT(400), YUP(400), YLOW(400), DELTY(400)
000002      DIMENSION ICFL(14)
000002      COMMON/A/W,P,FP,Y 005
000002      COMMON/B/TABLE 006
000002      COMMON/C/A 007
000002      DATA (TABLE=1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,15.,16., 008
000002      17.,18.,19.,20.,21.,22.,23.,24.,25.,26.,27.,28.,29.,30.,40.,60.,12 009
000002      10.,500., 010
000002      5A.3138,2.9200,2.3534,2.1318,2.0150,1.9472,1.8944,1.8595,1.8331, 011
000002      61.8125,1.7959,1.7823,1.7709,1.7613,1.7530,1.7459,1.7396,1.7341, 012
000002      71.7291,1.7247,1.7207,1.7171,1.7139,1.7109,1.7081,1.7056,1.7033, 013
000002      81.7011,1.6991,1.6973,1.6939,1.6707,1.6577,1.6449, 014
000002      1 12.706,4.3027,3.1825,2.7764,2.5706,2.4469,2.3646,2.3060, 015
000002      22.2422,2.2281,2.2010,2.1788,2.1604,2.1449,2.1315,2.1199,2.1098,2.1 016
000002      3009,2.0930,2.0860,2.0796,2.0739,2.0687,2.0639,2.0595,2.0555,2.0518 017
000002      4,2.0484,2.0452,2.0423,2.0211,2.0003,1.9799,1.9600) 018
000002      1 FCRMAT (12,A3,5Y,87)
000002      37 FCRMAT(3H X(12,1H)/125,12X,7F20,10) 020
000002      38 FCRMAT(29H(3H X(12,17H) AFTER REMOVING 12,14H(2HX(12,2H) ))) 021
000002      45 FCRMAT(5F20,10) 022
000002      66 FCRMAT(9H A-MATRIX /) 023
000002      67 FCRMAT(//20H INVERTED A-MATRIX (C-MATRIX) /) 024
000002      68 FCRMAT(//9H G-MATRIX /) 025
000002      70 FCRMAT(//11H C-A MATRIX/) 026
000002      75 FCRMAT(//70H REGRESSION COEFFICIENTS /) 027
000002      1660FCRMAT (//64H TOTAL CALCULATED FROM DATA C16FERS FROM TOTAL CALCUL 028
000002      1ATED BY SUMMING COMPONENTS BY F20,10//) 029
000002      A00 FCRMAT(14A4) 030
000002      A01 FCRMAT(217) 031
000002      A05 FCRMAT(3H R(12,4H) = F20,10) 032
000002      A06 FCRMAT( 2AL DUE TO REGRESSION 15,12X,7F20,10//15H DEVIATION FROM 033
000002      1/11H REGRESSIONY14,12X,2E20,10//AH TOTAL 119,12X,F20,10) 034
000002      A07 FCRMAT(12,2A4) 035
000002      A08 FCRMAT(2012) 036
000002      A14 FCRMAT(3H R(12,4H) = F20,10,10H +/- F20,10) 037
000002      A15 FCRMAT(15H VARIANCE ON Y(13,7H) =F20,10) 038
000002      A16 FCRMAT(3HBY(13,4H) = F20,10,10H +/- F20,10,5X,F20,10,F10,4) 039
000002      A1A1 FCRMAT ( 3HAY(13,4H) = F20,10,5X,F20,10,5XF20,10,5XF20,10 )
000002      A17 FCRMAT(//44H MULTIPLE CORRELATION COEFFICIENT (R) = F20,10// 040
000002      1 17H VARIANCE RATIO = F20,10//) 041
000002      A25 FCRMAT(4F20,10) 042
000002      A27 FCRMAT(5F20,10) 043
000002      A28 FCRMAT(//24H CONFIDENCE LIMITS OF R ) 044
000002      A51 FCRMAT(//17H COVARIANCES ON R//) 045
000002      A52 FCRMAT(9H REMOVING ) 046
000002      A53 FCRMAT(12X,12X,7F20,10) 047
000002      A55 FCRMAT(3H X'(12,10H) REMOVED 110,12X,3E20,10) 048
000002      A60 FCRMAT(//64H SOURCE DEGREES OF FREEDOM SUM OF THE SQUA 049
000002      1RES VARIANCE VARIANCE RATIO //) 050
000002      A61 FCRMAT(1H(12,15H(3H X(12,2H) ))) 051
000002      700 FCRMAT(17H RSS = F20,10) 052
000002      701 FCRMAT(17H B-NEW MATRIX//4(4F20,10//) 053

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000002      702 FORMAT(24H LEAVING OUT VARIABLE NO. I2//13H NEW C-MATRIX//)      054
000002      705 FORMAT(///)      055
000002      720 FORMAT(14H)      056
000002      721 FORMAT(67H,27H DEVIATION 0,0 )      057
000002      722 FORMAT(35H THE AVERAGE ABSOLUTE DEVIATION IS F10,4,0H PERCENT.)      058
000002      7221 FORMAT (30H ABSOLUTE AVERAGE DEVIATION = ,F20,10,20HCONFIDENCE FAC
      1TCR = ,F20,10)
000002      723 FORMAT(10H,10HINPUT DATA,///,5X,14H,15X,24H,X VALUE(S)-LEFT TO RIGHT      059
      1)      060
000002      724 FORMAT (R410)
000002      7241 FORMAT (1X,R410)
000002      726 FORMAT(///)
000002      1327 FORMAT(//21H ANALYSIS OF VARIANCE )      061
000002      1A2R FORMAT(//24H CONFIDENCE LIMITS OF Y )      062
000002      4Q40 FORMAT(10H,24H WITH LIMITS OF,13,11H PERCENT//)      063
000002      99 READ 600,INCFX      064
000010      READ 1,ARG(FSS,MNO,TYPF)      065
000022      READ 724, (ICELL(I),I=1,8)
000030      READ 601,M,N
000040      KKON = PD + 5 * NGUESS
000043      ENCODE(33,4940,FORM2)KKON      066
000052      PRINT 720      068
000056      PRINT 7241, (ICELL(I),I=1,8)
000064      PRINT 723,INCFX=0
000071      IF (MNO,FO,3H,CON)5,599
000076      5 MC=1 $JMC=1$NOTE=1      071
000100      DC 100 J=1,M      072
000102      100 CALL INDATA(Y(J),X(1,J),NOTE)      073
000111      AC TO H83      074
000111      599 MC=2$JMC=H830 3 J=1,M      075
000115      3 CALL INDATA(Y(J),X(1,J),NOTE)      076
000124      N=N-1      077
000125      AP3 PRINT 726      078
000131      CALL WEIGHT      079
000132      102 DC 104 I=1,M      080
000134      DC 104 J=1,N      081
000135      SLM=0.0      082
000136      DC 103 K=1,M      083
000150      103 SLM=SLM+W(K)*X(J,K)*X(I,K)      084
000154      104 A(I,J)=SLM      085
000164      CALL GALSQR(N,FP,A,C,WER)      086
000167      DC 107 I=1,N      087
000171      SLM=0.0      088
000172      DC 106 J=1,M      089
000202      106 SLM=SLM+W(J)*X(I,J)*Y(J)      090
000206      107 YX(I)=SLM      091
000212      DC 109 I=1,M      092
000214      SLM=0.0      093
000215      DC 108 K=1,N      094
000225      108 SLM=SLM+YX(K)*C(I,K)      095
000230      109 R(I)=SLM      096
000234      IF (INDEX(R),FO,2H,NO)111,4930      097
000241      4930 IF (INDEX(12),FO,3H,YFS) 1000,1001      098
000246      1000 PRINT 66      099
000252      DC 61 I=1,N      100
000254      61 PRINT 65, (A(I,J),J=1,M)      101
000273      1001 IF (INDEX(17),FO,3H,YES) 1002,1003      102
000300      1002 PRINT 67      103
      104

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000304	DC 60 I=1,N	105
000306	40 PRINT 65,(C(I,J),J=1,N)	106
000325	1003 IF (INDEX(10),EQ,3HYFS)42,43	107
000332	42 DC 44 I=1,N	108
000334	DC 44 J=1,N	109
000335	SLM=0.	110
000336	DC 45 K=1,N	111
000350	45 SLM=SUM+C(T,K)*A(K,J)	112
000354	44 CCOT(I,J)=SLM	113
000364	PRINT 70	114
000367	DC 71 I=1,N	115
000371	71 PRINT 65,(CCOT(T,J),J=1,N)	116
000410	43 IF (INDEX(14),EQ,3HYFS) 1004,1005	117
000415	1004 PRINT 68	118
000421	PRINT 65,(YX(I),I=1,N)	119
000430	1005 PRINT 75	120
000434	111 IF (INDEX(1),EQ,3HYFS)7,150	121
000441	7 DC 8 I=1,N	122
000443	K=Y-JWQ	123
000444	8 PRINT 605,W,R(I)	124
000457	150 DC 152 J=1,N	125
000461	YHAT(J)=0,N	126
000462	DC 152 I=1,N	127
000472	152 YHAT(J)=YHAT(J)+X(T,J)*R(I)	128
000500	SLM=0.0	129
000501	DC 153 J=1,N	130
000512	SLM=SUM+Y(J)	131
000513	153 YBAR=SUM/FLOAT (N)	132
000515	SSR=0.0	133
000515	DIVFR=0.0	134
000516	DIFF=0.0	135
000517	DC 154 J=1,N	136
000527	SSR=SSR+(YHAT(J)-YBAR)**2*(J)	137
000532	DIVFR=DIVFR+(Y(J)-YHAT(J))**2*(J)	138
000534	154 DIFF =DIFF +(Y(J)-YBAR)**2*(J)	139
000540	IF (MMQ.EQ,3HNCN)1006,1007	A
000545	1006 NCR=N-1	B
000547	GC TO 1008	C
000550	1007 NCR=N	D
000552	1008 NCFR=N-A	141
000554	NTOT = N -1	142
000555	SMNR=SSR/FLOAT (NCR)	143
000560	S2=DIVFR/FLOAT (NCFR)	144
000562	F=SMNR/S2	145
000563	IF (INDEX(2),EQ,3HYFS)151,200	146
000570	151 PRINT 1327	147
000574	PRINT 660	148
000600	PRINT 604,NCR,SSR,SMNR,F,NCFR,DIVFR,S2,NTCT,DIFF	149
000626	TCTAL = SSR+DIVFR	150
000630	DEV=DIFF-TOTAL	151
000631	IF (ABS (DEV)-1.NE-A)160,160,155	152
000635	155 PRINT 156, DEV	153
000643	160 PRINT 660	154
000647	DC 175 I=1,N	155
000654	NCFR=1	156
000655	S2=B(I)*R(I)/C(I,T)	157
000657	VPS=SS2	158
000660	P=VMS/S2	159

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000661      K=I-JM0
000663      175 PRINT 655,K,NDP,SS2,VMS,F
000704      147 IF (INDEX(1),FC,3HYFS)140,240
000711      140 PRINT 660
000715      READ 607,40,INDEX(A),INDEX(1)
000727      READ 608,(NSUR(I),I=1,NO)
000736      PRINT 652
000742      DC 157 J=1,40
000752      K=NSUR(J)+JM0
000753      147 RCT(J)=H(K)
000754      DC 158 J=1,40
000757      JL=NSUR(I)+JM0
000761      DC 158 K=1,40
000773      KK=NSUR(K)+JM0
000774      158 COUT(J,K)=C(JJ,K)
001004      IF (INDEX(4),FC,3HYFS)14,13
001010      14 S=AS=HOUT(1)*RDOT(1)/COUT(1)
001012      KA77=1
001013      F=S*AS/52
001015      PRINT 37,F,CLH(1),KA77,S*AS,C*AS,F
001032      DC 15 I=2,40
001034      CALL GALSQ(I,F,COUT,CINV,KER)
001037      DC 16 JK=1,I
001041      QP(JK)=0.
001042      DC 17 KL=1,I
001052      17 QP(JK)=QP(JK)+CINV(KL,JK)*RDOT(KL)
001055      16 QP(JK)=HOUT(JK)*QP(JK)
001062      S6=0.
001063      DC 18 JK=1,I
001070      18 S6=S6+QP(JK)
001072      VMS=S6-S*AS
001074      S*AS=S6
001075      F=VMS/52
001076      K=I-1
001101      ENCODE (45,78,FORM)K
001110      PRINT FCRV,ASLB(I),(NSUR(J),J=1,K)
001121      15 PRINT 653,KA77,VMS,VMS,F
001140      13 CALL GALSQ(NC,FP,COUT,CINV,KER)
001144      DC 164 JK=1,40
001146      QP(JK)=0.0
001147      DC 163 KL=1,40
001157      163 QP(JK)=QP(JK)+CINV(KL,JK)*RDOT(KL)
001162      164 QP(JK)=HOUT(JK)*QP(JK)
001167      S6=0.0
001170      DC 165 J=1,40
001175      165 S6=QP(JK)+S6
001177      VMS=S6/FLCAT (NC)
001201      F=VMS/52
001203      ENCODE (18,66,FORM)NC
001213      PRINT FCRV,(NSUR(I),I=1,NC)
001222      PRINT 653,NC,S6,VMS,F
001236      DC TO 167
001237      200 IF (INDEX(7),FC,3HYFS)201,250
001244      201 DC 203 I=1,4
001246      DC 203 J=1,4
001256      203 CCVAR(I,J)=C(I,J)*S2
001263      PRINT 651
001266      DC 205 I=1,4

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001270	205 PRINT 627.(COVAR(T,J),J=1,N)	218
001307	PRINT 628	219
001312	PRINT FCW3	220
001316	250 IF (INDEX(A),FC,THYFS)251,300	221
001323	251 DF=FLOAT (M=N)	222
001325	I=1	223
001327	252 IF (TABLE(T,1)-DF)253,255,254	224
001332	253 I=I+1	225
001334	GO TO 252	226
001343	254 TL=I-1	227
001344	X1=TABLE(TL,NGUFS)	228
001345	X2=TABLE(T,AGLFS)	229
001345	Y1=TABLE(TL,1)	230
001347	Y2=TABLE(T,1)	231
001351	TE=X1-(Y1-DF)*(Y1-Y2)/(Y1-Y2)	232
001357	240 IF (INDEX(A),FC,THYFS)256,360	233
001364	255 TE=TABLE(T,AGLFS)	234
001370	256 DO 257 I=1,N	235
001372	TLTM=TE*SCOT (S2=C(T,1))	236
001400	K=I-JM	237
001403	257 PRINT 614,K,H(T,TLTM	238
001417	300 IF (INDEX(C),FC,THYFS)301,350	239
001424	301 PRINT 705	240
001430	DO 305 IJ=1,M	241
001432	VARI(IJ)=0,0	242
001433	DO 303 K=1,N	243
001435	GL(IJK)=0,0	244
001436	DO 302 K=1,M	245
001451	302 GL(IJK)=X(K,I,T)*C(KL,K)+S1(IJK)	246
001454	303 GL(IJK)=S1(IJK)+X(K,T,J)	247
001463	DO 304 K=1,N	248
001470	304 VARI(IJ)=VARI(TJ)+GL(IJK)	249
001473	VA=VARI(IJ)*S2	250
001475	305 PRINT 615,T,VA	251
001510	PRINT 706	252
001513	250 IF (INDEX(A),FC,THYFS)251,400	253
001520	251 IF (INDEX(C),FC,THYFS)257,350	254
001525	252 DO 355 I=1,M	255
001527	VARI(IJ)=0,0	256
001530	DO 354 K=1,N	257
001532	GL(IJK)=0,0	258
001533	DO 353 K=1,M	259
001546	353 GL(IJK)=X(K,I,T)*C(KL,K)+S1(IJK)	260
001551	354 GL(IJK)=S1(IJK)+X(K,T,J)	261
001560	DO 355 K=1,N	262
001565	355 VARI(IJ)=VARI(TJ)+GL(IJK)	263
001572	257 IF (INDEX(A),FC,THYFS)260,251	264
001577	260 PRINT 1628	265
001603	PRINT FCW3	266
001607	SCFLY=0.	267
001610	SCFLY=0.	
001611	PRINT 721	268
001614	DO 358 I=1,M	269
001617	DEL Y=Y(I)-V*AT(T)	270
001621	PCV=100.*SCFLY/Y(I)	271
001622	SCFLY=SCFLY+ABS(DEL Y)	
001625	SCFLY=SCFLY+ABS (ENDY)	272
001630	TLTM=TE*SCOT (S2=VARI(I))	273

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001626      758 PRINT 616,T,YHAT(I),TLIM,DELTY,PDY
001656      IF (TYPE,FC,7MSF,LOG) 3582,7583
001662      7582 CCNTINUE
001662      PRINT 724
001666      AVDFLY=SHFLY/FLCAT(M)
001670      CCNFAC=10.**AVDFLY
001674      DC 3581 I=1,M
001676      TLIM=TE*SQRT (S2*VARI(I))
001705      YHAT(I)=10.**YHAT(I)
001711      YLP(I)=10.**(YHAT(I)+TLIM)
001716      YLOW(I)=10.**(YHAT(I)-TLIM)
001723      DELTY(I)=YUP(I)-YLOW(I)
001725      7581 PRINT 616,I,YHAT(I),YUP(I),YLOW(I),DELTY,I
001744      PRINT 724
001751      PRINT 7221,AVDFLY,CCNFAC
001761      7583 CCNTINUE
001761      PRINT 724
001765      SPDY=SPDY/FLCAT (M)
001767      PRINT 722,SPDY
001775      400 IF (INDEX(7),FC,7HYFS)401,500
002002      401 R =SSR/DIFF
002004      F=SSR/(S2*FLCAT (N-1))
002010      PRINT 617,R,F
002017      500 IF (INDEX(9),FC,7HYFS)501,2
002024      501 DC 504 I=1,A
002026      DC 503 J=1,A
002027      DC 502 K=1,A
002047      502 CA(J,K)=C(J,K)-(C(I,I)*C(K,I))/C(I,I)
002053      BSTAR(J)=B(I)-(F(I)*C(J,I))/C(I,I)
002063      503 HSS=R(I)*R(I)/C(I,I)
002072      IF=I-JMG
002074      PRINT 702,IF
002101      DC 506 K=1,A
002103      506 PRINT 625,(C(K,J),J=1,N)
002122      PRINT 705
002125      PRINT 701,(BSTAR(J),J=1,N)
002134      PRINT 705
002140      PRINT 700,BSS
002146      504 PRINT 705
002155      2 READ 600,UMG
002163      IF (MMQ,EG,4HMCFF)99,993
002170      993 CCNTINUE
002171      FND

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PROGRAM LENGTH INCLUDING I/O BUFFERS
040302

FUNCTION ASSIGNMENTS

STATEMENT ASSIGNMENTS

1	=	002201	2	=	002156	5	=	000077	7	=	000442
13	=	001141	14	=	001011	37	=	002244	38	=	002211
42	=	000333	43	=	000411	65	=	002220	66	=	002223
67	=	002226	68	=	002233	70	=	002236	75	=	002242
99	=	000003	102	=	000133	111	=	000435	150	=	000440
151	=	000571	155	=	000636	154	=	002250	160	=	000644

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